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OF
WASHINGTON

YEAR BOOK No. 20

1921

MARINE BIOLOGICAL LABORATORY
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WASHINGTON, FEBRUARY 1922

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President of the Institution.
JOHN C. MERRIAM.

Trustees.

ELIHU ROOT, *Chairman.*
CHARLES D. WALCOTT, *Vice-Chairman.*
CLEVELAND H. DODGE, *Secretary.*

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CLEVELAND H. DODGE.
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HERBERT HOOVER.
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Auditing Committee.

R. S. BROOKINGS, *Chairman.*
CHARLES L. HUTCHINSON.
GEORGE W. WICKERSHAM.

*Ex-officio member.

LIST OF PRESENT AND FORMER TRUSTEES.

*Alexander Agassiz,	1904–05	*Seth Low,	1902–16
*John S. Billings,	1902–13	*Wayne MacVeagh,	1902–07
Robert S. Brookings,	1910–	*D. O. Mills,	1902–09
*John L. Cadwalader,	1903–14	*S. Weir Mitchell,	1902–14
John J. Carty,	1916–	Andrew J. Montague,	1907–
Cleveland H. Dodge,	1903–	William W. Morrow,	1902–
*William E. Dodge,	1902–03	James Parmelee,	1917–
Charles P. Fenner,	1914–	Wm. Barclay Parsons,	1907–
Simon Flexner,	1910–14	Stewart Paton,	1915–
W. Cameron Forbes,	1920–	George W. Pepper,	1914–20
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Lyman J. Gage,	1902–12	Elihu Root,	1902–
*Daniel C. Gilman,	1902–08	Martin A. Ryerson,	1908–
*John Hay,	1902–05	Theobald Smith,	1914–
Myron T. Herrick,	1915–	*John C. Spooner,	1902–07
*Abram S. Hewitt,	1902–03	William H. Taft,	1906–15
*Henry L. Higginson,	1902–19	Charles D. Walcott,	1902–
*Ethan A. Hitchcock,	1902–09	Henry P. Walcott,	1910–
*Henry Hitchcock,	1902–02	William H. Welch,	1906–
Herbert Hoover,	1920–	*Andrew D. White,	1902–16
*William Wirt Howe,	1903–09	*Edward D. White,	1902–03
Charles L. Hutchinson,	1902–	Henry White,	1913–
*Samuel P. Langley,	1904–06	George W. Wickersham,	1909–
*William Lindsay,	1902–09	Robert S. Woodward,	1905–
Henry Cabot Lodge,	1914–	*Carroll D. Wright,	1902–08

*Deceased.

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904:

The President of the United States.
The President of the Senate.
The Speaker of the House of Representatives.
The Secretary of the Smithsonian Institution.
The President of the National Academy of Sciences.

STAFF OF INVESTIGATORS FOR YEAR 1921.

Department of Botanical Research:

Daniel T. MacDougal, Director.
William A. Cannon.
J. M. McGee.
Forrest Shreve.
H. A. Spoehr.
Godfrey Sykes.

Department of Embryology:

George L. Streeter, Director.
Chester H. Heuser.
Margaret R. Lewis.
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A. H. Schultz.

Department of Genetics:

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H. H. Laughlin, Assistant Director.
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H. J. Banker.
A. M. Banta.
John Belling (temporary).
A. F. Blakeslee.
A. H. Estabrook.
M. E. Farnham.
J. A. Harris.
E. C. MacDowell.
C. W. Metz.
Elizabeth B. Muncey.
Louise A. Nelson.
Oscar Riddle.
E. R. Rose (temporary).
F. W. Saunders (temporary).

Geophysical Laboratory:

Arthur L. Day, Director.
L. H. Adams.
Eugene T. Allen.
M. Arousseau.
N. L. Bowen.
Pentte Escola.
C. N. Fenner.
R. H. Lombard.
H. E. Merwin.
G. W. Morey.
Eugen Posnjak.
H. S. Roberts.
E. S. Shepherd.
F. Hastings Smyth.
Robert B. Sosman.
H. S. Washington.
Walter P. White.
E. D. Williamson.
Fred E. Wright.
R. W. G. Wyckoff.
E. G. Zies.

Department of Historical Research:

J. Franklin Jameson, Director.
Edmund C. Burnett.
Frances G. Davenport.
Shirley Farr.
Waldo G. Leland.
Charles O. Paullin.
Leo F. Stock.

Department of Marine Biology:

Alfred G. Mayor, Director.

Investigators connected with this Department during the year.

Paul Bartsch (U. S. National Museum).
Ulric Dahlgren (Princeton University).
John H. Gerould (Dartmouth College).
E. N. Harvey (Princeton University).
A. L. Treadwell (Vassar College).
William H. Longley (Goucher College).
Asa A. Schaeffer (University of Tennessee).

Department of Meridian Astrometry:

Benjamin Boss, Director.
Sebastian Albrecht.
Sherwood B. Grant.
Heroy Jenkins.
Harry Raymond.
W. B. Varnum.
Ralph E. Wilson.

Staff of Investigators for Year 1921—*Continued.*

Mount Wilson Observatory:

George E. Hale, Director.
Walter S. Adams, Assistant Director.
Alfred H. Joy, Secretary.
F. H. Seares, Supt. Computing Division.
A. S. King, Supt. Physical Laboratory.
J. A. Anderson.
Harold D. Babcock.
J. C. Duncan.
Ferdinand Ellerman.
Edwin P. Hubble.
Paul W. Merrill.
Seth B. Nicholson.
Francis G. Pease.
Edison Pettit.
R. F. Sanford.
Gustaf Stromberg.
Harlow Shapley.
Charles E. St. John.
A. van Maanen.

Nutrition Laboratory:

Francis G. Benedict, Director.
Marion L. Baker.
T. M. Carpenter.
E. L. Fox.
Mary F. Hendry.
Alice Johnson.
W. R. Miles.
E. S. Mills.

Department of Terrestrial Magnetism:

Louis A. Bauer, Director.
J. P. Ault.
S. J. Barnett.
F. Brown.
D. G. Coleman.
C. R. Duvall.
H. M. W. Edmonds.
C. C. Ennis.
H. W. Fisk.
J. A. Fleming.
R. H. Goddard.
H. R. Grummann.
J. E. Ives (temporary).
H. F. Johnston.
S. J. Mauchly.
R. R. Mills.
W. C. Parkinson.
W. J. Peters.
J. Shearer.
A. Thomson.
G. R. Wait.
W. F. Wallis.

Ecological Research:

Frederic E. Clements, Associate.
G. W. Goldsmith.
H. M. Hall.
Frances L. Long.
G. V. Loftfield.

Middle American Archæology:

Sylvanus G. Morley, Associate.
Carl E. Guthe, Research Associate.

Physiological Chemistry:

T. B. Osborne, Research Associate (Connecticut Agric. Exper. Station).
L. B. Mendel, Research Associate (Yale University).
A. J. Wakeman.
C. S. Leavenworth.
Helen Cannon.

Biology:

T. H. Morgan, Research Associate (Columbia University).
T. B. Bridges.
A. H. Sturtevant.

Other Investigators Primarily Connected with Institution:

Henry Bergen, Research Associate in Early English Literature.
Oliver P. Hay, Associate in Palæontology.
Elias A. Lowe, Associate in Palæography.
Albert Mann, Research Associate in Biology.
George Sarton, Associate in the History of Science.
Esther B. Van Deman, Associate in Roman Archæology.
George R. Wieland, Associate in Palæontology.
Harry O. Wood, Research Associate in Seismology.

Additional Research Associates connected with other Institutions:

Carl Barus (Brown University), Physics.
John S. Bassett (Smith College), History.
V. Bjerknes (University of Bergen, Norway), Meteorology.
E. C. Case (University of Michigan), Palæontology.
W. E. Castle (Harvard University), Biology.
T. C. Chamberlin (University of Chicago), Geology.
B. M. Duggar (Missouri Botanical Garden), Botany.
H. D. Fish (University of Pittsburgh), Zoology.
J. W. E. Glattfeld (University of Chicago), Botany.
John F. Hayford (Northwestern University), Physics.
J. C. Kapteyn (University of Groningen), Astronomy.
B. E. Livingston (Johns Hopkins University), Botany.
A. A. Michelson (University of Chicago), Astronomy.
Frank Morley (Johns Hopkins University), Mathematics.
F. R. Moulton (University of Chicago), Mathematical Physics.
E. L. Nichols (Cornell University), Physics.
A. A. Noyes (California Institute of Technology), Chemistry.
T. W. Richards (Harvard University), Chemistry.
J. N. Rose (U. S. National Museum), Botany.
Henry N. Russell (Princeton University), Astronomy.
H. C. Sherman (Columbia University), Chemistry.
Edgar F. Smith (University of Pennsylvania), Chemistry.
John S. P. Tatlock (Leland Stanford Junior University), Literature.

ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington.* (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

Public No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

Sec. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

Sec. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

Sec. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

Sec. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

Sec. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

TWENTY-SECOND MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF THE TWENTY-SECOND MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington in the Board Room of the Administration Building, on Friday, December 9, 1921, and was called to order at 10 a. m. by the Chairman, Mr. Root.

Upon roll-call the following Trustees responded: Robert S. Brookings, John J. Carty, Cleveland H. Dodge, Charles P. Fenner, W. Cameron Forbes, Charles L. Hutchinson, Andrew J. Montague, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Henry S. Pritchett, Elihu Root, Charles D. Walcott, Henry P. Walcott, William H. Welch, Henry White, George W. Wickersham, Robert S. Woodward. The President of the Institution, Dr. John C. Merriam, was also present.

The minutes of the twenty-first meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments, Associates, and Research Associates of the Institution were presented and considered.

The following resolutions were passed:

Resolved, That the income of the Colburn Fund which will accrue on and after January 1 1922, shall be regarded as available for appropriation.

Resolved, That appropriations on account of the Insurance Fund shall be continued, beginning with the year 1922, in such amounts as may be sufficient, together with the estimated income on this Fund to total $25,000 annually, said total to be added to the principal of the Fund until otherwise ordered.

The following appropriations for the year 1922 were authorized:

Insurance Fund	$11,000
Pension Fund	40,000
Administration	60,000
Publication (including Division of Publications)	94,500
Departments of Research	960,624
Middle American Archæology	19,000
Associates of Institution	18,600
Minor Grants	156,900
Index Medicus	17,500
General Contingent Fund	45,000
Total	$1,423,124

The following officers of the Board and the following members of committees were reelected for a period of three years:

Officers of the Board: Chairman, Mr. Root; Vice-Chairman, Mr. Charles D. Walcott; Secretary, Mr. Dodge.

Members of the Executive Committee: Messrs. Parsons, Paton, and Pritchett.

Members of the Finance Committee: Mr. Dodge (chairman) and Messrs. Pritchett and Wickersham.

Members of the Auditing Committee: Mr. Brookings (chairman) and Messrs. Hutchinson and Wickersham.

The meeting adjourned at one o'clock.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1921

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1921, along with provisional recommendation of appropriations for the ensuing year.

Twentieth Anniversary.

This report marks completion of the twentieth year of organized research conducted by the Institution. The original aim of the Founder was to give encouragement and support to investigations or to constructive thought in any department of science, literature, or art. It is gratifying to make record of the fact that at the end of this second decade the function of research as an activity indispensable to civilization and as a necessary prerequisite of progress seems to have come into fuller recognition than at any previous time in history. Industrial and governmental agencies, as well as academic interests, have given to fundamental investigation a high place in the list of elements essential for advance. To-day one may say with confidence that no investment of funds or of personal effort can find a work of greater dignity and worth, or one which offers a future giving clearer evidence of abundant and continuing reward, than is open in the field of research. This was the vision of the Founder, and its realization will continue in growing measure as the complex problems of future years require added emphasis upon constructive thought.

In Memoriam.

It is with sincere sorrow that record is made of the death of Edward Douglass White, Chief Justice of the Supreme Court of the United States. Mr. Justice

White was named as a member of the original Board of Trustees of the Carnegie Institution of Washington in Mr. Carnegie's Deed of Trust. He was absent from the first session of the Board on January 29, 1902, but attended the session on the day following. His resignation as a member of the Board was dated November 6, 1903, and was presented and accepted at the third meeting on December 8, 1903.

Mr. White took a vigorous part in discussion of the affairs of the Institution. He favored restricting initial commitments of the Institution for support of investigation to periods not exceeding five years, and was a strong supporter of the plan to establish the reserve fund which has become so important to the Institution in the past year.

Reference to Accomplishments of the Year.

The only adequate review of progress in the work of the Institution during the past year must comprise a complete statement of researches conducted by our departments and Associates and a list of contributions to knowledge through publications or through other expression of results made available to the public. The reports of departments and of Associates forming the major part of the Year Book of the Institution cover the interesting and important researches of the year. The statement of work completed is also given in part through the list of volumes issued by the Institution and by the bibliography of papers published through other channels.

The work of the Institution touches in one way or another upon nearly all of the principal fields of research. The investigations have been very fruitful. They have not merely produced contributions to knowledge, but are also the basis for much research of application which goes immediately into human use.

It seems neither necessary nor desirable in this preliminary statement to do more than call attention to some of the most significant results which have signalized certain phases of our work in the past year.

An Epoch-making Discovery in Astronomy.

It is doubtful whether any recent discovery in the physical sciences has attracted wider interest or has contributed more to the ultimate possibilities of astronomical and physical science than the measurement of diameter of a fixed star carried out at Mount Wilson Observatory three days subsequent to the annual meeting of the Institution last year. This long-desired result was made possible by many years of development of plant and technique, together with the extraordinary skill of Dr. Michelson and his associates and the clear vision of Dr. Hale in bringing together all of the elements required for this particular task. Measurement of the diameter of the star Betelgeuse once accomplished, the dimensions of other stars followed quickly. More recently, by refinement of the original method, Dr. Michelson has opened the way for corresponding observations on a group of stars which seemed to be entirely out of range in the first use of the interferometer on the 100-inch telescope. The results already accomplished give confirmation of much important work done by other astronomers and furnish a new starting-point for a great variety of investigations concerning the nature of the universe. In consideration of the critical problems which are now at the front for discussion, provision has been made for securing assistance and cooperation of other investigators. The work of Dr. H. N. Russell, of Princeton University, which has added much to an understanding of the evolution of the stars, is fortunately now associated with that of Dr. Michelson and others in helping to solve the special problems to which Mount Wilson Observatory has given attention.

Completion of major work of the ship Carnegie.

A significant event in the operations of the Institution is the completion within this year of a survey of the seas of the world by the non-magnetic ship *Carnegie*. Launched in 1909, this unique vessel has voyaged nearly 300,000 miles, covering the principal areas of the great oceans and securing previously unavailable data on magnetic conditions which, with those obtained by concurrent studies on land, give a map of magnetic variations not heretofore possible.

With completion of the year's cruise by the *Carnegie,* and the summing up of its results, attention may be directed more particularly to land observations, to critical studies of terrestrial and atmospheric electricity, to experimental studies bearing upon the nature of magnetism, and to assembling and interpreting the great mass of data made available from all sources through many years of field work.

Department of Genetics and International Congress of Eugenics.

Beginning with the year 1921, the Department of Experimental Evolution and the Eugenics Record Office have come to function as an administrative unit known as the Department of Genetics. This change brings the biological studies of inheritance, based upon investigation of many groups of plants and animals, to bear more directly on studies of human genetics conducted through the Eugenics Record Office. Important as knowledge of heredity is in its application to development of the animals and plants which contribute to meet our needs, there is no group of questions more significant in the complicated organization of human society than those concerning the meaning and the possibility of direction or control of inheritance in man. Without full understanding of the biological factors concerned, it might appear that intelligence and social organization have brought relatively large opportunity for degeneration. On the other hand, adequate understanding of the principles governing the course of descent may give to mankind opportunity for more rapid and more advantageous development than has been known in the past lines of evolution of other organisms.

In the course of the last year the International Congress of Eugenics held in New York City contributed much toward betterment of our understanding of these problems. The Director and many members of the staff of the Department of Genetics gave much time and effort to support of the program of contributions covered by the International Congress, and, reciprocally, the Congress has assisted materially in furnishing a better basis for future stages in the work of this department.

New Chemical Laboratory for Botanical Research.

In the past year a modest chemical laboratory has been erected for the Department of Botanical Research at Carmel, California. This Department has carried its work farther into the field of physical and chemical research in the effort to secure more information concerning the basis of plant activities. The new laboratory offers improved opportunity for fundamental work on photosynthesis or the chemistry of compounds arising under the influence of light. It is hoped that with present facilities a nearer approach to the solution of this difficult but fundamental problem in the physiology of plants may be obtained.

Advance of Studies on Ancient Maya Civilization.

An important project in the purely humanistic field is that concerning the ancient Maya civilization of Central America. The expedition of 1921, led into this region by Dr. S. G. Morley, has secured most significant new materials in study of the ancient monuments and in excavation of building sites. The story of this people contributes much that may become critical or determinative in our interpretation of early American history, and we know that the great bulk of this record still remains unread. In the past year the Institution has had the benefit of effective cooperation in this work by Mr. William Gates, whose study of both modern and ancient Maya language involves significant lines of investigation which should relate themselves closely to the archæological studies. Mr. Gates has made available to the Institution his large collection of Maya manuscripts and of general literature on Middle American work, and the data contained therein will be of much value for future researches.

Investigations by Research Associates.

In addition to important results secured through investigations organized and supported by the Institution, it has been our privilege to help in the advance of much significant work conducted by distinguished investigators connected with other organizations. In the course of the past year the Institution has cooperated in this manner with Dr. T. H. Morgan, of Columbia University, in the forwarding of his epoch-making studies in experimental evolution. We have cooperated also with Dr. Thomas B. Osborne, of the Connecticut Agricultural Experiment Station, and Dr. L. B. Mendel, of Yale University, in their exceedingly important investigations of the vitamins, which are playing so significant a rôle in fundamental biological research and in investigations of nutrition.

Similar arrangements with Dr. A. A. Michelson, of the University of Chicago, and Dr. H. N. Russell, of Princeton University, have brought into association with the staff of Mount Wilson Observatory investigators whose recent contributions rank among the foremost results in the physical sciences.

In still another field of separate research lies the work of Dr. John F. Hayford, of Northwestern University, whose studies upon the physical factors determining the water-level of the Great Lakes have taken high rank among researches advanced toward completion within the past year.

Publication and Distribution of Results.

The formulation of results of the Institution's work is represented in part by the series of Carnegie Institution publications, but in a large measure the work of the Departments and Associates is issued through many other publications established for needs of investigators in special subjects. A survey of the list of works issued by the Institution presented on page 17, compared with the bibliography of the members of the staff on pages 18 to 27, will indicate that certain of the departments very largely use channels other than our own publications. This difference in distribution occurs by reason of the fact that the results in some subjects may be expressed in such form as to fit easily into special journals, whereas other types of work are presented more effectively in the form of monographic volumes. Thus, for example, the papers of the Geophysical Laboratory appear largely through the American Journal of Science, the publications of Mount Wilson Observatory are issued in considerable part in the Astrophysical Journal, while many of the results coming from the Department of Terrestrial Magnetism are printed in the journal Terrestrial Magnetism and Atmospheric Electricity. Although the Institution is proud of its own publications, the same gratification in accomplishment is justified by the papers, large and small, which go from the Institution to the public through other series.

Distribution of volumes issued directly under the auspices of the Institution has been extended this year to reach agencies doing important research only in limited or special fields. With the purpose of bringing the results of our work into effective use as quickly as possible, the distribution to individual investigators of reputation has also been increased. At the same time arrangement has been made for material reduction in the sale price of the more expensive works to be issued in the future.

In the past year special effort has been made to handle a considerable accumulation of publications awaiting their turn at the press. During the war, and up to this year, cost of printing increased very rapidly and limited the output of volumes. In 1920 a considerable part of the appropriation was required to pay for publication of books authorized prior to the great increase in cost of printing, and only eight new contributions were accepted. Nearly all the older manuscripts have now been published and we are attempting to keep the date of issue of all new papers reasonably close to the period of acceptance. Such an arrangement means much gain through early use of results obtained in our researches. In the past year, in addition to the regular appropriation, a sum of $10,000 was added to the publication fund and recommendations for the coming year include a corresponding increase of $10,000.

Researches on New Problems Considered.

Although it may be difficult to define precisely the function of the Institution in general or at any particular moment, it is clearly the duty of this organization to lend its aid, wherever possible, to advance fundamental knowledge in fields which are not normally covered by the efforts of other agencies, or in which other research bodies may find difficulty in initiation of projects. It is evident that as a part of its purpose the Institution must look forward to giving its support in putting into operation researches upon some of these more difficult subjects. We could be helpful in cases of this nature through use of our organization as an initiating mechanism, although the ultimate conduct of the investigations might be under other auspices.

Problems which promise large return for such future investigation are found in the field of seismology or earthquake study and in the general region of human behavior considered in the widest sense and recognized as a problem of strictly biological or physical research rather than as a question of sociology. In the course of the year the Institution has been interested in studies in these fields.

In seismology, an advisory committee has been organized under the chairmanship of Dr. Arthur L. Day, Director of the Geophysical Laboratory. Seven of the leading students of geological science and of physics have accepted membership in the committee and have done much to bring into close and active cooperation the various agencies of the country concerned with earthquake studies. Within the short time in which this committee has been in operation it has gone far to place seismological research in a position to make material advance in our understanding of movements of the earth's crust, and thereby ultimately to contribute much toward maintenance of the security and happiness of people inhabiting earthquake regions.

An investigation into the problems of human behavior, constituting the second subject to be examined, has been given only brief consideration. It represents one of the most difficult of all researches, but is not second to any other question in the possibilities offered. Without reference to immediate practical use of knowledge of human behavior in control of our affairs, research in this field offers an exceptional opportunity for work on the biological or physical basis of human behavior and on the significance of individual and group differences. In the present status of this question the study concerns mainly the nature of present knowledge and the approaches to research which seem to offer the largest possibilities for securing new points of view or new combinations of effort that may open aspects of the work not previously considered.

Proposals for Extension of Department Activities.

In addition to new problems for which the Institution has contributed only the mechanism for preliminary or initial studies, attention should be called to the fact that certain of the departments now in existence may with profit extend their investigations into other stages promising large results based upon the work already accomplished. Mention may be made here of the work of the Geophysical Laboratory, a unique institution devoting itself to fundamental questions of physics and chemistry relating to the composition and structure of the earth's crust. The work already completed has not only set science forward to a relatively advanced position in knowledge of problems originally fixed as the goal, but it is further to the credit of the Institution that the fundamental researches, conducted without reference to application, have contributed much to an understanding of certain critical questions in the field of applied physics and chemistry.

A review of the present situation indicates that advance of investigations in the Geophysical Laboratory in such a manner as to take full advantage of results already secured makes it desirable to extend the facilities required for high-pressure research. For the conduct of this work it would be desirable to have a small building erected as a unit separate from the present laboratory. New apparatus specially adapted for high-pressure work would be a requisite for the further researches proposed, and the reorganization incident to carrying forward these studies should be supported by addition of several specialists and assistants to the staff.

The extraordinary advances made in researches conducted at Mount Wilson Observatory since the war have opened up entirely new possibilities, not only in the field of observational astronomy but in the combination of physics with astronomy so ably and effectively organized in the work of the laboratory. A large measure of the success of the Observatory is due to combination of physical and astronomical studies. In addition to opening great opportunities for observation by use of exceptional telescopes, the Observatory has aimed to check, interpret, and extend its results by physical investigations conducted in the laboratory. Thus it has been possible to secure the information needed to give adequate understanding of the temperature of the sun-spots. Many of the most recent discoveries serve to emphasize the need for further development of laboratory studies to supplement and interpret the data secured by use of the great telescope. While the apparatus available promises large contributions in the near future, there is reason for considering the extension of laboratory facilities in order that the remarkable materials being secured through observational work may attain their fullest value by comparison with results of laboratory experiments.

A further need, which is real though not urgent, involves the proposal made some years ago to secure a special building for the Department of Embryology in order that quarters for the conduct of this exceptional work may be secured in close association with the Department of Anatomy of Johns Hopkins University.

Financial Statement for Fiscal Year 1920–1921.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted at the end of the year are shown in detail in the following statement:

Financial statement for fiscal year 1920–1921.

Object of appropriation.	Balances unallotted Oct. 31, 1920.	Appropriation Dec. 12, 1920.	Revertments Nov. 1, 1920, to Oct. 31, 1921.	Totals for fiscal year.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1921.
Large Grants..	....	$966,162.00	$49,774.49	$1,015,936.49	$1,015,936.49	....
Minor Grants..	$11,520.95	265,820.53	45,892.87	323,234.35	318,348.56	$4,885.79
Publications...	5,149.00	85,000.00	18,382.23	108,521.23	99,199.91	9,331.32
Administration.	....	55,000.00	1,800.00	56,800.00	56,800.00	....
Insurance Fund	....	25,000.00	....	25,000.00	25,000.00	....
Pension Fund..	....	40,000.00	....	40,000.00	40,000.00	....
Total........	16,699.95	1,436,982.53	115,849.59	1,569,502.07	1,555,284.96	14,217.11

Receipts and Expenditures of the Institution to Date.

The aggregates of receipts from interest on endowment, from interest on bond investments and bank deposits, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is $20,486,013.89.

Aggregates of financial receipts.

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
1902	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068 84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,112,441.25	159,559.03	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,112,441.25	170,211.22	16,684.51	4,068.69	210,518.96	1,513,924.63
Total	16,532,349.12	1,150,112.73	186,266.42	171,206.95	*2,446,078.67	20,486,013.89

*Of this amount, $1,444,335 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, 1917, 1918, and 1921; $51,265.74 from the Colburn Estate in 1916; and $900,000 from the Carnegie Corporation of New York in 1917, 1918, 1919, 1920, and 1921.

The following list shows the departments and divisions for which appropriations have been made by the Trustees and the amounts allotted by the Executive Committee during 1921:

Department of Botanical Research	$69,550.00
Ecological Research	31,442.00
Department of Embryology	44,140.00
Department of Genetics	125,974.03
Geophysical Laboratory	137,736.00
Department of Historical Research	45,250.00
Department of Marine Biology	33,400.00
Department of Meridian Astrometry	40,512.00
Nutrition Laboratory	47,098.00
Mount Wilson Observatory	209,209.41
Department of Terrestrial Magnetism	231,625.05
Aggregate for Minor Grants	150,908.33
Aggregate for Publications	99,199.91
Total	1,266,044.73

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor and special projects; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Purposes for which funds have been appropriated.

Year ending Oct. 31.	Investments in bonds.	Large projects.	Minor and special projects.	Publications.	Administration.	Total.
1902	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
Total	5,396,288.22	10,565,303.41	2,316,612.47	934,698.11	927,257.96	20,140,160.17

Investments in Property.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the sum of $3,129,908.83 has been expended since the foundation of the Institution. A schedule of real estate and equipment is given under the report of the Auditor on page 40.

Sales of Publications and Value of those on hand.

The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903.....	$2,256.91	$29.25	....
1904.....	2,370.47	52.85	$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
Total...	80,029.51	1,118.26	105,118.65

At the end of the fiscal year there are on hand 93,333 volumes of miscellaneous publications and Year Books, having a sale value of $284,281.75; also 34,777 numbers of the Index Medicus, having a sale value of $20,089.25. The total sale value of publications on hand is therefore $304,371. It is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 226,039 volumes of publications of the Institution.

Growth and Extent of Institution's Publications.

The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. 442 volumes, embracing a total of 124,161 pages of printed matter, have thus far been issued by the Institution.

Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the twenty years from 1902 to 1921.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902......	3	46	....	46
1903......	3	1,667	....	1,667
1904......	11	2,843	34	2,877
1905......	21	3,783	1,445	5,228
1906......	19	3,166	1,288	4,454
1907......	38	6,284	3,428	9,712
1908......	28	4,843	2,485	7,328
1909......	19	3,695	1,212	4,907
1910......	29	3,274	4,831	8,105
1911......	30	5,062	1,670	6,732
1912......	23	3,981	2,044	6,025
1913......	29	6,605	2,752	9,357
1914......	23	4,978	1,934	6,912
1915......	23	4,686	1,466	6,152
1916......	35	9,478	2,430	11,908
1917......	21	4,464	2,691	7,155
1918......	17	3,073	1,269	4,193
1919......	29	5,834	2,431	8,265
1920......	23	3,962	3,710	7,672
1921......	18	4,068	1,398	5,466
Total...	442	85,792	38,369	124,161

Publications Authorized and Issued during the Year.

The publication of 23 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $61,300. The following list gives the titles and names of authors of the publications issued during the year; it includes 18 volumes, with an aggregate of 4,068 octavo pages and 1,398 quarto pages. Twenty additional volumes are now in press.

List of publications issued during the year.

Year Book, No. 19, 1920. Octavo, xxi+424 pages, 2 plates, 5 figures.
Index Medicus, Second Series, Vol. 18, 1920. Octavo, 1,131 pages.
Ninth edition of an illustrated pamphlet on the Scope and Organization of the Carnegie Institution of Washington. Octavo, 59 pages, 1 plate, 1 map, 29 figures.
No. 185. Hasse, Adelaide R. Index to United States Documents relating to Foreign Affairs, 1828–1861. In three parts. Quarto, Part III, R to Z, 647 pages.
No. 214. Clark, H. L. The Echinoderm Fauna of Torres Strait: Its Composition and its Origin. (Paper from Department of Marine Biology of the Carnegie Institution of Washington. Vol. X.) Quarto, viii+233 pages, 40 plates.
No. 258. Rowe, L. S. Federal System of the Argentine Republic. Octavo, vii+161 pages.
No. 275. Contributions to Embryology, No. 56. Vol. XII. Quarto, 364 pp, 24 pls., 6 figs.
  Mall, F. P., and A. W. Meyer. Studies on Abortuses: A Survey of the Pathologic Ova in the Carnegie Embryological Collection.
No. 276. Contributions to Embryology, Nos. 57 to 64. Vol. XIII. Quarto, 146 pages, 15 plates, 25 figures, 1 chart.
  Cash, James R. Lymphatics in the Stomach of the Embryo Pig. (Contribution No. 57.) 3 plates, 3 figures.
  Reichert, F. L. On the Fate of the Primary Lymph-Sacs in the Abdominal Region of the Pig, and the Development of Lymph-Channels in the Abdominal and Pelvic Regions. (Contribution No. 58.) 5 figures.
  Jenkins, George B. Relative Weight and Volume of the Component Parts of the Brain of the Human Embryo at Different Stages of Development. (Contribution No. 59.) 12 figures, 1 chart.
  Corner, George W. Abnormalities of the Mammalian Embryo occurring before Implantation. (Contribution No. 60.) 2 plates, 1 figure.
  Spaulding, M. H. Development of the External Genitalia in the Human Embryo. (Contribution No. 61.) 4 plates, 2 figures.
  Wislocki, George B. Further Experimental Studies on Fetal Absorption. (Contribution No. 62.)
    III. Behavior of the Fetal Membranes and Placenta of the Guinea-Pig toward Trypan-Blue injected into the Maternal Blood-Stream.
    IV. Behavior of the Placenta and Fetal Membranes of the Rabbit toward Trypan-Blue injected into the Maternal Blood-Stream. 1 plate.
  Wislocki, George B., and J. A. Key. Distribution of Mitochondria in the Placenta. (Contribution No. 63.) 1 plate.
  Corner, G. W. Cyclic Changes in the Ovaries and Uterus of the Sow, and Their Relation to Mechanism of Implantation. (Contribution No. 64.) 4 plates, 2 figures.
No. 284. Livingston, Burton E., and Forrest Shreve. Distribution of Vegetation in the United States as related to Climatic Conditions. Octavo, xvi+590 pages, 73 plates, 74 figures, 152 tables.
No. 299. Burnett, E. C. Letters of Members of the Continental Congress. Vol. 1: August 29, 1774, to July 4, 1776. Octavo, lxvi+572 pages.
No. 300. Ivens, Walter G. A Grammar and Dictionary of the Lau Language. Octavo, 64 pages, 3 plates.
No. 301. Sturtevant, A. H. The North American Species of *Drosophila*. Octavo, iv+150 pages, 3 plates, 49 figures.
No. 302. Benedict, F. G., and F. B. Talbot. Metabolism and Growth from Birth to Puberty. Octavo, vi+213 pages, 55 figures.
No. 303. Carpenter, Thorne M. Tables, Factors, and Formulas for computing Respiratory Exchange and Biological Transformations of Energy. Octavo, 123 pages, 33 tables.
No. 305. Banta, Arthur M. Selection in Cladocera on the Basis of a Physiological Character. Octavo, 170 pages, 19 figures.
No. 307. MacDougal, D. T. Growth in Trees. Octavo, 41 pages, 16 figures.
No. 313. Hall, Harvey M., and Frances L. Long. Rubber-content of North American Plants. Octavo, 65 pages, 3 plates.
No. 315. Clements, F. E. Aeration and Air-Content: The Role of Oxygen in Root Activity. Octavo, 183 pages.

APPENDIX.

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications proceeding from work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (p. 17).

Adams, L. H. The compressibility of diamond. Jour. Wash. Acad. Sci., vol. 11, 45–50 (1921).

———. Note on the measurement of the density of minerals. Amer. Mineral., vol. 6, 11–12 (1921).

———, and E. D. Williamson. The annealing of glass. (Papers on Optical Glass, No. 32.) Jour. Franklin Inst., vol. 190, 597–631; 835–870 (1920).

Adams, Walter S., and Alfred H. Joy. The spectrum of Nova Cygni, 1920. Pubs. A. S. P., vol. 32, 276-278 (1920).

———, ———. The spectrum of o Ceti near minimum of light. Pubs. A. S. P., vol. 33, 107–110 (1921).

———, ———. Spectroscopic observations of the distant companion of Capella. Pubs. A. S. P., vol. 33, 112 (1921).

———, ———. The spectrum of the companion to α Scorpii. Read at the Berkeley meeting, A. S. P. (1921); Pubs. A. S. P., vol. 33, 206 (1921).

———, ———. Evidence regarding the giant and dwarf division of stars afforded by recent Mount Wilson parallaxes. Read at Chicago meeting, Amer. Astron. Soc. (1920); Pubs. Amer. Astron. Soc., 25th meeting, 201–202; Pop. Astron., vol. 29, 141–143 (1921).

———, ———. Note on the comparison of spectral types determined at Harvard and Mount Wilson. Read at Chicago meeting, Amer. Astron. Soc. (1920); Pubs. Amer. Astron. Soc., 25th meeting, 202–203; Pop. Astron., vol. 29, 143–144 (1921).

———, ———. Gustaf Strömberg, and Cora G. Burwell. The parallaxes of 1646 stars derived by the spectroscopic method. Astrophys. Jour., vol. 53, 13–94 (1921); Mt. Wilson Contr., No. 199.

———, and Frederick H. Seares. Comparative tests of the 100-inch and 60-inch reflectors. Pubs. A. S. P., vol. 33, 31–34 (1921).

———, and Gustaf Strömberg, and Alfred H. Joy. The relationship of absolute magnitude to space-velocity. Astrophys. Jour., vol. 54, 9–27 (1921); Mt. Wilson Contr., No. 210.

Albrecht, Sebastian. Personality in the estimation of tenths. Astron. Jour., No. 781 (Dec. 1920).

———. Additional evidence on changes of wave-length which are progressive with stellar type. (Abstract) Pop. Astron., vol. 29 (Mar. 1921).

Ault, J. P. Preliminary results of ocean magnetic observations on the *Carnegie* from Colombo, Ceylon, to Fremantle, Western Australia, and Lyttelton, New Zealand, July to October, 1920. Terr. Mag., vol. 25, No. 4, 167–172 (Dec. 1920).

———. Results of ocean magnetic observations on the *Carnegie* from Lyttelton to Tahiti, Fanning Island, San Francisco, and Honolulu, November, 1920, to April, 1921. Terr. Mag., vol. 26, Nos. 1–2, 15–24 (Mar.-June 1921).

———. Preliminary results of ocean magnetic observations on the *Carnegie* from Honolulu to Pago Pago, April to June, 1921. Terr. Mag., vol. 26, No. 3, 91–95 (Sept. 1921).

Babcock, Harold D. See St. John, Charles E.

Baker, Marion L. See Benedict, F. G.

Banta, A. M. Selection in Cladocera. Anat. Rec., vol. 20, 212 (Jan. 1921).

———. Flat-fish with unusual pigmented areas. Anat. Rec., vol. 20, 214–215 (Jan.1921).

———. An eyeless daphnid, with remarks on the possible origin of eyeless cave animals. Science, n. s., vol. 53, 462–463 (May 13, 1921).

———. A convenient culture medium for daphnids. Science, n. s., vol. 53, 557–558 (June 17, 1921).

Barnett, L. J. H. See Barnett, S. J.

Barnett, S. J. Molecular and cosmical magnetism. Nature, vol. 107, No. 2679, 8–9 (Mar. 3, 1921).

———. The electron theory of magnetism. Science, n. s., vol. 53, No. 1377, 465–475 (May 20, 1921).

———, and L. J. H. Barnett. Additional experiments on the nature of the magnetic molecule. (Abstract) Phys. Rev., vol. 17, No. 3, 404–405 (Mar. 1921).

Bauer, L. A. Some of the chief problems in terrestrial magnetism and electricity. Proc. Nat. Acad. Sci., vol. 6, No. 10, 572–580 (Oct. 1920).

———. On vertical electric currents and the relation between terrestrial magnetism and atmospheric electricity. Terr. Mag., vol. 25, No. 4, 145–162 (Dec. 1920).

Bauer, L. A. Measures of the electric and magnetic activity of the Sun and the Earth, and interrelations. Terr. Mag., vol. 26, Nos. 1–2, 33–68 (Mar.–June 1921).

———. Note regarding the "Earth-effect" on solar activity and relation with terrestrial magnetism. Terr. Mag., vol. 26, No. 3, 113–115 (Sept. 1921).

Behre, E. H. See **Riddle, O.**

Belling, John. See **Blakeslee, A. F.**

Benedict, Cornelia Golay, and F. G. Benedict. The energy content of extra foods (sandwiches). Boston Med. and Surg. Jour., vol. 184, 436 (1921).

Benedict, Francis G., The measurement and standards of basal metabolism. Jour. Amer. Med. Assoc., vol. 77, 247 (1921).

———, and **Warren E. Collins.** A clinical apparatus for measuring basal metabolism. Boston Med. and Surg. Jour., vol. 183, 449 (1920).

———, **Edward L. Fox,** and **Marion L. Baker.** The surface temperature of the elephant, rhinoceros, and hippopotamus. Amer. Jour. Physiol., vol. 56, 464 (1921).

———, and **Mary F. Hendry.** The energy requirements of girls from 12 to 17 years of age, Boston Med. and Surg. Jour., vol. 184, pp. 217, 257, 282, 297, and 329 (1921).

———, ———, and **Marion L. Baker.** The basal metabolism of girls 12 to 17 years of age. Proc. Nat. Acad. Sci., vol. 7, 10 (1921).

———. See **Harris, Arthur J.**

v. Bichowsky, F. R., and H. E. Merwin. Silica-glass prism for refractometry of liquids at elevated temperatures. Jour. Opt. Soc. Amer., vol. 5, 441–443 (1921).

Bjerknes, J., and H. Solberg. Meteorological conditions for the formation of rain. Geofysiske Publik., No. 3, vol. 2 (1921).

Bjerknes, V. On the dynamics of the circular vortex, with applications to the atmosphere and atmospheric vortex and wave motion. Geofysiske Publik., No. 4, vol. 2 (1921).

Blakeslee, A. F. A dwarf mutation in Portulaca, showing vegetative reversions. Genetics, vol. 5, 419–433 (July 1920).

———. Mutations in mucors. Jour. Hered., vol. 11, 278–284, figs. 26–28 (July–Aug. 1920; Feb. 5, 1921).

———. A graft-infectious disease of *Datura* resembling a vegetative mutation. Jour. Genet., vol. 11, 17–36, pls. II–VI, figs. 1–12 (Apr. 1921).

———. A chemical method of distinguishing genetic types of yellow cones in *Rudbeckia.* Zeit. induk. Abst. und Vererb., vol. 25, 211–221, pl. 9 (1921).

———. The globe mutant in the jimson weed (*Datura stramonium*). Genetics, vol. 6, 241–264 (May 1921).

———. Types of mutations and their possible significance in evolution. Amer. Nat., vol. 55, 254–267 (May–June 1921).

———, with **John Belling** and **M. E. Farnham.** Chromosomal duplication and Mendelian phenomena in *Datura* mutants. Science, n. s., vol. 52, 388–390 (Oct. 22, 1920).

———. See **Harris, J. Arthur.**

Bowen, N. L. Tridymite crystals in glass. Amer. Mineral., vol. 4, 65–66 (1919).

———. Abnormal birefringence of torbernite. Amer. Jour. Sci., vol. 48, 195–198 (1919).

———. Cacoclosite from Wakefield, Quebec. Amer. Jour. Sci., vol. 48, 440–442 (1919).

———. Crystallization-differentiation in igneous magmas. Jour. Geol., vol. 27, 393–430 (1919).

———. Echellite, a new mineral. Amer. Mineral., vol. 5, 1–2 (1920).

———. Differentiation by deformation. Proc. Nat. Acad. Sci., vol. 6, 159–162 (1920).

———. Diffusion in silicate melts. Jour. Geol., vol. 29, 295–317 (1921).

———. Preliminary note on monticellite alnoite from Isle Cadieux, Quebec. Jour. Wash. Acad. Sci., vol. 11, 278–281 (1921).

Bowman, H. H. M. Histological variations in *Rhizophora mangle.* 22d Report Mich. Acad. Sci., 129-134, pls. 9–12 (1920).

Boyer, Sylvester. See **Richards, Theodore W.**

Brackett, Frederick S. An examination of the infra-red spectrum of the sun, λ8900–9900. Astrophys. Jour., vol. 53, 121–132 (1920); Mt. Wilson Contr., No. 197.

Burwell, Cora G. See **Adams, Walter S.**

Caldwell, M. L. See **Sherman, H. C.**

Card, L. E. See **Harris, J. Arthur.**

Carver, Emmett K. See **Richards, Theodore W.**

Castle, W. E. A new type of inheritance. Science, n. s., vol. 53, 339–342 (Apr. 8, 1921).

———. Genetics of the "Chinchilla" rabbit. Science, n. s., vol. 53, 387–388 (Apr. 22, 1921).

———. On a method of estimating the number of genetic factors concerned in cases of blending inheritance. Science, n. s., vol. 54, 93–96 (July 29, 1921).

———. An improved method of estimating the number of genetic factors concerned in cases of blending inheritance. Science, n. s., vol. 54, 223 (Sept. 9, 1921).

Chamberlin, Thomas C. Groundwork of the Earth's diastrophism. Bull. Geol. Soc. Amer., vol. 32, 197–210 (June 30, 1921).

———. The greater Earth. Bull. Geol. Soc. Amer., vol. 32, 211–226 (June 30, 1921).

———. Diastrophism and the formation processes: XIV. Groundwork for the study of megadiastrophism. Jour. Geol., vol. 29, No. 5, 391–425 (July–Aug. 1921).

Coble, A. B. Multiple binary forms with the closure property. Amer. Jour. Math., vol. 43, 1–19 (Jan. 1921).

Collins, Warren E. See Benedict, F. G.

Corner, George W. Internal migration of the ovum. Johns Hopkins Hosp. Bull., vol. 32, 78–83 (Mar. 1921).

———. The ovarian cycle in swine. Science, n. s., vol. 53, 420–421 (1921).

———. Cyclic changes in the ovaries and uterus of the sow, and their relation to the mechanism of implantation of the embryos. Anat. Rec., vol. 21, 52 (1921).

Cunningham, R. G. Studies in placental permeability: I. The differential resistance to certain solutions offered by the placenta in the cat. Amer. Jour. Physiol., vol. 53, 439–456 (1920).

———. Studies on absorption from serous cavities: III. The effect of dextrose upon the peritoneal mesothelium. Amer. Jour. Physiol., vol. 53, 488–494 (1920).

Cushman, J. A. Foraminifera from the north coast of Jamaica. Proc. Nat. Mus., vol. 59, 47–82, pls. 11–19 (1921).

Davenport, C. B. The best index of build. Quart. Pub. Amer. Statis. Asso., 342–344 (Sept. 1920).

———. Height-weight index of build. Amer. Jour. Phys. Anthrop., vol. 3, No. 4, 467–475 (1920).

———. Heredity of constitutional mental disorders. Psychol. Bull., vol. 17, No. 9, 300–310 (Sept. 1920).

Davis, Harold S. See Richards, Theodore W.

Davis, Helen. See Shapley, Harlow.

Duncan, John C. The spectroscopic orbit of the Cepheid variable X Cygni. Astrophys. Jour., vol. 53, 95–98 (1921); Mt. Wilson Contr., No. 196.

———. Bright and dark nebulæ near ζ Orionis photographed with the 100-inch Hooker telescope. Astrophys. Jour., vol. 53, 392–396 (1921); Mt. Wilson Contr., No. 209.

———. Novæ in the Andromeda nebula. Pubs. A. S. P., vol. 33, 56–57 (1921).

———. Two new variable stars in the Trifid nebula. Pubs. A. S. P., vol. 33, 207–208 (1921).

Durham, G. B. See Harris, J. Arthur.

Ellerman, Ferdinand. A few remarks on "dark lightning." Pop. Astron., vol. 29, 139–141 (1921).

———. See Hale, George E.

Farnham, M. E. See Blakeskee, A. F.

Fleming, J. A. Latest annual values of the magnetic elements at observatories. Terr. Mag., vol. 25, No. 4, 179–181 (Dec. 1920).

Fox, Edward L. See Benedict, F. G.

Gibbons, Marion. See Little, C. C.

Gortner, R. A., and J. Arthur Harris. Note on the occurrence of *Gammarus limnœus* in a saline habitat. Science, n. s., vol. 53, 460–462 (1921).

———. See Harris, J. Arthur.

Greene, C. H. See Shipley, P. G.

Greenhill, J. P. A histological study of fetus and implantation site in a case of missed abortion. Amer. Jour. Obst. and Gyn., vol. 2, 188–194 (1921).

Hale, George E. A summary of the year's work at Mount Wilson. Pubs. A. S. P., vol. 33, 18–30 (1921).

———. Note on the combined effect of electric and magnetic fields on the hydrogen spectrum. Pubs. A. S. P., vol. 33, 114–116 (1921).

———. One-hundred-inch telescope of the Mount Wilson Observatory. London Times (July 26, 1921).

———. The angular diameter of α Orionis. Monthly Notices, vol. 81, 166–167 (1921).

———. Some tests of the 100-inch Hooker telescope. Nature, vol. 105, 266–268 (1920).

———. Chapters from "The New World of Science," Introduction, Science and War, War Services of the National Research Council; The possibilities of co-operation in research; The international organization of research. (1920.)

———. The new heavens. Scribner's Mag., vol. 68, 387–402 (1920).

———. Giant stars. Scribner's Mag., vol. 70, 3–15 (1921).

———, and Ferdinand Ellerman. The Mount Wilson photographic map of the sun-spot spectrum. Pubs. A. S. P., vol. 32, 272–273 (1920).

———, and Seth B. Nicholson. The great sun-spot of May, 1921. Read at Berkeley meeting, A. S. P. (1921); (Abstract) Pubs. A. S. P., vol. 33, 208 (1921).

Hanke, M. C. See Riddle, O.

Harris, J. Arthur. Decrease in stature: Note on the statures of the medico-actuarial investigations. Quart. Pub. Amer. Statis. Asso., vol. 17, 219–221 (1920).

———. Formulæ for the determination of the correlations of size and growth increments in the developing organism. Proc. Soc. Exper. Biol. and Med., vol. 18, 4–5 (1920).

———. Tissue weight and water content in a tetracotyledonous race of *Phaseolus vulgaris*. Proc. Soc. Exper. Biol. and Med., vol. 18, 207–209 (1921).

Harris, J. Arthur. Leaf-tissue production and water content in a mutant race of *Phaseolus vulgaris*. Bot. Gaz., vol. 72, 151–161 (1921).

———, and F. G. Benedict. Besoins vitaux types d'énergie pour la nutrition humaine. Bull. Soc. Sci. d'hygiène alimentaire de l'homme, vol. 8, 434–454 (1920).

———, ———. The variation and the statistical constants of basal metabolism in man. Jour. Biol. Chem., vol. 46, 257–279 (1921).

———, R. A. Gortner, W. F. Hoffman, and A. T. Valentine. Maximum values of osmotic concentration in plant-tissue fluids. Proc. Soc. Exper. Biol. and Med., vol. 18, 106–109 (1921).

———, ———, and J. V. Lawrence. On the differentiation of the leaf-tissue fluids of ligneous and herbaceous plants with respect to osmotic concentration and electrical conductivity. Jour. Gen. Phys., vol. 3, 343–345 (1921).

———, ———, ———. The osmotic concentration and electrical conductivity of the tissue fluids of ligneous and herbaceous plants. Jour. Phys. Chem., vol. 25, 122–146 (1921).

———, ———, ———. On the relationship between freezing-point lowering, Δ, and specific electrical conductivity, k, of plant-tissue fluids. Science, n. s., vol. 52, 494–495 (1920).

———, W. F. Kirkpatrick, A. F. Blakeslee, D. E. Warner, and L. E. Card. The egg records of limited periods as criteria for predicting the egg production of the White Leghorn fowl. Genetics, vol. 6, 265–309 (1921).

———, and Harry R. Lewis. The second-year record of birds which did and which did not lay during individual months of the pullet year. Science, n. s., vol. 54, 224–226 (1921).

———, and H. S. Reed. Inter-periodic correlation in the analysis of growth. Biol. Bull., vol. 40, 243–258 (1921).

———, and C. S. Scofield. Permanence of differences in the plots of an experimental field. Jour. Agric. Res., vol. 20, 335–356 (1920).

———, and Edmund W. Sinnott. The vascular anatomy of normal and variant seedlings of *Phaseolus vulgaris.* Proc. Nat. Acad. Sci., vol. 7, 35–41 (1921).

———, ———, John Y. Pennypacker, and G. B. Durham. The vascular anatomy of dimerous and trimerous seedlings of *Phaseolus vulgaris.* Amer. Jour. Bot., vol. 8, 63–102 (1921).

———, ———, ———, ———. Correlations between anatomical characters in the seedling of *Phaseolus vulgaris.* Amer. Jour. Bot., vol. 8, 339–365 (1921).

———, and A. T. Valentine. The specific electrical conductivity of the tissue fluids of desert Loranthaceæ. Proc. Soc. Exper. Biol. and Med., vol. 18, 95–97 (1920).

———. See Gortner, R. A.

Hay, Oliver P. Description of species of Pleistocene Vertebrata, types or specimens of most of which are preserved in the United States National Museum. Proc. U. S. Nat. Mus., vol. 59, 599–642, pls. 116–124 (Oct. 13, 1921).

Hendry, Mary F., and Alice Johnson. Carbon-dioxid content of barn air. Jour. Agri. Research, vol. 20, 405 (1920).

———. See Benedict, Francis G.

Heuser, C. H. The early establishment of the intestinal nutrition in the opossum. The digestive system just before and just after birth. Amer. Jour. Anat., vol. 28, 341–369 (1921).

———. Development of the innominate artery in the pig. Anat. Rec., vol. 21, 67 (1921).

Hoffman, W. F. See Harris, J. Arthur.

Hoge, Wendell P. The Mount Wilson Observatory. Santa Fé Mag., vol. 15, 21–27 (1921).

Hopper, F. L. See Merrill, Paul W.

Howes, H. L. The spectral structure of the luninescence excited by the hydrogen flame. Phys. Rev. (2), vol. 17, 469 (1921).

Hubble, Edwin P. Twelve new planetary nebulæ. Pubs. A. S. P., vol. 33, 174–175 (1921).

Huffer, C. M. See Wilson, Ralph W.

Hughson, Walter. See Weed, L. H.

Humason, Milton L. Two new planetary nebulæ. Pubs. A. S. P., vol. 33, 175 (1921).

———, and Paul W. Merrill. Ten stars of class B having the H*α* line bright. Second list. Pubs. A. S. P., vol. 33, 112–114 (1921).

———. See Merrill, Paul W.

Jameson, J. Franklin. John Clark of the *Mayflower.* Proc. Mass. Hist. Soc., vol. 14, 61-76 (1921).

———. The arrival of the Pilgrims. Brown Univ., 40 pages (1921).

———. American Council of Learned Societies. Amer. Hist. Review, vol. 25, 440-446 (1921).

———. Meeting of the American Historical Association at Washington. Amer. Hist. Rev., vol. 26, 413–439 (1921).

Johnson, Alice. See Hendry, Mary F.

Johnson, F. P. The later development of the urethra in the male. Jour. Urol., vol. 4, 447–501 (1920).

Joy, Alfred H. See Adams, Walter S.

Keith, Clyde R. See Merrill, Paul W.

Kidson, Edward. Records of earthquakes at Watheroo Magnetic Observatory. Terr. Mag., vol. 25, No. 4, 174 (Dec. 1920).

King, Arthur S. Experiments on the possible influence of potential difference on the radiation of the tube-resistance furnace. Astrophys. Jour., vol. 52, 187–197 (1920); Mt. Wilson Contr., No. 193.

———. Intensity differences in furnace and arc among the component series in band spectra. Astrophys. Jour., vol. 53, 161–164 (1921); Mt. Wilson Contr., No. 194.

———. The variation with temperature of the electric-furnace spectrum of manganese. Astrophys. Jour., vol. 53, 133–143 (1921); Mt. Wilson Contr., No. 198.

———. The electric furnace spectrum of scandium. Astrophys. Jour., vol. 54, 28–44 (1921); Mt. Wilson Contr., No. 211.

———. Experiments with the tube-resistance furnace on the effect of potential difference. Proc. Nat. Acad. Sci., vol. 6, 701–702 (1920); Mt. Wilson Communications, No. 71.

———. The silicon line λ3906 in the electric-furnace spectrum. Pubs. A. S. P., vol. 33, 106–107 (1921).

———. The leading features of the electric-furnace spectrum of scandium. Pubs. A. S. P., vol. 33, 175–177 (1921).

———. Further observations on the furnace absorption-spectrum of iron. Pubs. A. S. P., vol. 33, 177–178 (1921).

———. Recent observations of absorption spectra. Read at Berkeley meeting, Amer. Phys. Soc. (1921); (Abstract) Phys. Rev., vol. 18, 335, 336 (1921).

King, C. V. See Riddle, O.

Kirkpatrick, W. F. See Harris, J. Arthur.

Krepelka, Henry. See Richards, Theodore W.

Kuntz, Albert. The development of the sympathetic nervous system in man. Jour. Comp. Neurol., vol. 32, 173–229 (1920).

Laughlin, H. H. Biological aspects of immigration. Hearings before the committee on immigration and naturalization. House of Rep., 66th Cong., 2d Sess., Wash., Apr. 16–17, 1920; 1–26, Govt. Print. Office (1921).

———. Race assimilation by the pure-sire method. Jour. Hered., vol. 11, No. 6, 259–263 (July-Aug. 1920).

———. Calculating ancestral influence in man: A mathematical measure of the facts of bisexual heredity. Jour. Genet., vol. 5, 435–458 (Sept. 1920).

———. Eugenical sterilization in United States. Soc. Hyg., vol. 6, No. 4, 499–532 (Oct. 1920).

———. Eugenics in Germany. Eugenics Rev., vol. 12, No. 4, 304–307 (Jan. 1921).

———. The socially inadequate: How shall we designate and sort them? Amer. Jour. Soc., vol. 27, No. 1, 54–70 (July 1921).

———. Dice-casting and pedigree selection. Experiments which picture mathematically close analogies between dice-casting and certain breeding phenomena. Jour. Genet., vol. 6, 384–398 (July 1921).

Lawrence, J. V. See Harris, J. Arthur.

Leavenworth, Charles S. See Osborne, T. B.

Leland, Waldo G. The International Union of Academies and the American Council of Learned Societies, International Conciliation, pages 442–457 (Sept. 1920).

———. The organization of the International Union of Academies and of the American Council of Learned Societies. Bull. A. C. L. S., 1–7 (1921).

Lewis, H. R. See Harris, J. Arthur.

Lewis, M. R. Granules in the cells of chick embryos produced by egg albumin in the medium of tissue cultures. Jour. Exper. Med., vol. 33, 485–493 (1921).

———. The formation of vacuoles in tissue cultures owing to the lack of dextrose in the media. Anat. Rec., vol. 21, 71 (1921).

Lewis, W. H. The effect of potassium permanganate on the mesenchyme cells of tissue-cultures. Amer. Jour. Anat., vol. 28, 431–445 (1921).

———. The characteristics of the various types of cells found in tissue-cultures from chick embryos. Anat. Rec., vol. 21, 71 (1921).

———. Smooth muscle and endothelium in tissue-cultures. Anat. Rec., vol. 21, 72 (1921).

———, and L. T. Webster. Migration of lymphocytes in plasma cultures of human lymph nodes. Jour. Exper. Med., vol. 33, 261–269 (1921).

———, ———. Giant cells in cultures from human lymph nodes. Jour. Exper. Med., vol. 33, 349–360 (1921).

Lindblad, Bertil. Några intryck från Mount Wilson Observatoriet. Pop. Astron. Tidskrift, vol. 1 (1921).

Lineback, P. E. A case of unilateral polydactyly in a 22-mm. embryo. Anat. Rec., vol. 20, 313–319 (1920).

Little, C. C. Factors influencing the growth of a transplantable tumor in mice. Jour. Exper. Zool., vol. 31, 307-326 (1920).

———. Note on the occurrence of a probable sex-linked lethal factor in mammals. Amer. Nat., vol. 54, 457–460 (1920).

———. Is the fertile tortoise-shell tom cat a modified female? Jour. Genet., vol. 10, 301–302 (1920).

LITTLE, C. C. Non-disjunction of the fourth chromosome of *Drosophila*. Science, n. s., vol. 53, 167 (1921).

———, and MARION GIBBONS. Evidence for sex-linked lethal factors in man. Proc. Soc. Exper. Biol. and Med., vol. 18, 111–115 (1921).

———. See STRONG, L. C.

LOWE, E. A. The oldest extant manuscript of the *Abstrusa* and *Abolita* glossaries. Class. Quart., vol. 15, 189 *et seq.* (1921).

———. Review of *Collectanea Hispanica* by C. U. Clark. English Hist. Rev., vol. 36, 463 (July 1921).

———. Die Haupt-Handschriften des Apicius. Berliner Philologische Wochenschrift, vol. 40, 1174 *et seq.* (1920).

LYNCH, R. S. The cultivation in vitro of liver cells from the chick embryo. Amer. Jour. Anat., vol. 29, 281–308 (1921).

MACDOUGAL, D. T. Growth in trees. Proc. Amer. Phil. Soc., vol. 60, 7–14 (1921).

———. Effects of age and of the inclusion of salts on the heterotropic action of colloidal bodies of cytological interest. Proc. Soc. Exper. Biol. and Med., vol. 18, 244–246 (1921).

———. The reactions of plants to new habitats. Ecology, vol. 2, 1–20 (1921).

———. Water deficit and the action of vitamines, amino-compounds, and salts on hydration. Amer. Jour. Bot., vol. 8, 296–302 (1921).

———. The action of bases and salts on biocolloids and cell-masses. Proc. Amer. Phil. Soc., vol. 60, 15–30 (1921).

———. A new high-temperature record for growth. Science, n. s., vol. 53, 370–372 (1921).

———, and EARL B. WORKING. Another high-temperature record for growth and endurance. Science, n. s., vol. 54, 152–153 (1921).

MACDOWELL, E. C., and E. M. VICARI. Alcoholism and the behavior of white rats: I. The influence of alcoholic grandparents upon maze-behavior. Jour. Exper. Zool., vol. 33, 209–291 (May 1921).

MAUCHLY, S. J. Note on the diurnal variation of the atmospheric-electric potential-gradient. Phys. Rev., vol. 18, No. 2, 161–162 (Aug. 1921).

MENDEL, LAFAYETTE B. The fat-soluble vitamine. N. Y. State Jour. Med., vol. 20, 212–217 (July 1920).

———. See OSBORNE, T. B.

MERRILL, PAUL W. Characteristic behavior of the bright lines in stellar spectra of class Md. Astrophys. Jour., vol. 53, 185–200 (1921); Mt. Wilson Contr., No. 200.

———. Observations of the nebular lines in the spectrum of the long-period variable star R Aquarii. Astrophys. Jour., vol. 53, 375–379 (1921); Mt. Wilson Contr., No. 206.

———. A special field of usefulness for small telescopes. Pubs. A. S. P., vol. 32, 318–321 (1920).

———. Note on the spectrum of R Cygni. Read at Berkeley meeting, A. S. P. (1921); Pubs. A. S. P., vol. 33, 206–207 (1921).

———. Interferometer observations of double stars. Read at Berkeley meeting, A. S. P. (1921); (Abstract) Pubs. A. S. P., vol. 33, 209 (1921).

———, F. L. HOPPER, and CLYDE R. KEITH. Identification of air lines in spark spectra from $\lambda 5927$ to $\lambda 8683$. Astrophys. Jour., vol. 54, 76–77 (1921); Mt. Wilson Contr., No. 207.

———, and MILTON L. HUMASON. Ten stars of class B having the $H\alpha$ line bright. Pubs. A. S. P., vol. 32, 336–337 (1920).

———. See HUMASON, MILTON L.

MERWIN, H. E. See v. BICHOWSKY, F. R.; WASHINGTON, H. S.

METZ, CHARLES W. A simple method of handling small objects in making microscopic preparations. Anat. Rec., vol. 21, No. 4, 373-374 (July 1921).

———, and JOSÉ F. NONIDEZ. Spermatogenesis in the fly *Asilus sericeus* Say. Jour. Exper. Zool., vol. 23, No. 1, 165–185 (Jan. 1921).

MEYER, A. W. The frequency and cause of abortion. Amer. Jour. Obst. and Gyn., vol. 2, 138–156 (1921).

MICHELSON, A. A. On the application of interference methods to astronomical measurements. Read at Chicago meeting, Amer. Phys. Soc. (1921); (Abstract) Phys. Rev., vol. 17, 405–406 (1921).

———, and FRANCIS G. PEASE. Measurement of the diameter of α Orionis with the interferometer. Astrophys. Jour., vol. 53, 249–259 (1921); Mt. Wilson Contr., No. 203.

MILES, W. R. A pursuitmeter. Psychol. Bull., vol. 18, 102 (1920); Jour. Exp. Psychol., vol. 4, 77 (1921).

———. The quantitative measurement of static control in standing. Amer. Jour. Physiol., vol. 55, 309 (1921).

MILLER, C. H. Demonstration of the cartilaginous skeleton in mammalian fetuses. Anat. Rec., vol. 20, 415–419 (1921).

NICHOLS, E. L., and D. T. WILBER. The luminescence of certain oxides sublimed in the electric arc. Phys. Rev. (2), vol. 17, 707 (1921).

———, ———. Flame excitation of luminescence. Phys. Rev. (2), vol. 17, 453 (1921).

———, ———. Luminescence at high temperatures. Proc. Nat. Acad. Sci., vol. 6, 693 (Dec. 1920).

Nicholson, Seth B. Sun-spot activity during 1920. Pubs. A. S. P., vol. 33, 54–56 (1921).

———. See Hale, George E.; St. John, Charles E.

Nolan, Owen L. See Osborne, T. B.

Nonidez, José F. See Metz, Charles W.

Ogawa, Chikanosuke. Experiments on the orientation of the ear vesicle in amphibian larvæ. Jour. Exper. Zool., vol. 34, 17–43, (1921).

Osborne, Thomas B. The water-soluble vitamine. N. Y. State Jour. Med., vol. 20, 217–222 (July 1920).

———, and Charles S. Leavenworth. The effect of alkali on the efficiency of the water-soluble vitamine B. Jour. Biol. Chem., vol. 45, 423–426 (Feb. 1921).

———, and Lafayette B. Mendell. The occurrence of water-soluble vitamine in some common fruits. Jour. Biol. Chem., vol. 42, 465–489 (July 1920).

———, ———. Skimmed milk as a supplement to corn in feeding. Jour. Biol. Chem., vol. 44, 1–4 (Oct. 1920).

———, ———. Growth on diets poor in true fats. Jour. Biol. Chem., vol. 45, 145–152 (Dec. 1920).

———, ———. A critique of experiments with diets free from fat-soluble vitamine. Jour. Biol. Chem., vol. 45, 277–288 (Jan. 1921).

———, ———. Does growth require preformed carbohydrate in the diet? Proc. Soc. Exper. Biol. and Med., vol. 18, 136–137 (Mar. 1921).

———, ———. Growth on diets containing more than 90 per cent of protein. Proc. Soc. Exper. Biol. and Med., vol. 18, 167–168 (Mar. 1921).

———, ———. Ophthalmia and diet. Jour. Amer. Med. Asso., vol. 76, 905–908 (Apr. 2, 1921).

———, ———. La oftalmia y el regimen. Jour. Amer. Med. Asso., Edicion Espanol, vol. 5, 503–506 (Apr. 15, 1921).

———, and Owen L. Nolan. Does gliadin contain amide nitrogen? Jour. Biol. Chem., vol. 43, 311–316 (Sept. 1920).

Park, E. A., and G. F. Powers. Acrocephaly and scaphocephaly with symmetrically distributed malformations of the extremities. Amer. Jour. Dis. Child., vol. 20, 235–315 (1920).

Parkinson, W. C. The magnetic storm of May 13–17, 1921, at Watheroo Observatory, Australia. Terr. Mag., vol. 26, Nos. 1–2, 26–28 (Mar.–June 1921).

Pease, Francis G. The planetary disks of Nova Aquilæ No. 3. Pubs. A. S. P., vol. 32, 334–335 (1920).

———. The angular diameter of α Bootis by the interferometer. Pubs. A. S. P., vol. 33, 171–173 (1921).

———. The diameter of α Scorpii by the interferometer method. Read at Berkeley meeting, A. S. P. (1921); Pubs. A. S. P., vol. 33, 204–205 (1921).

———. The diameter of α Orionis by Michelson's interferometer method. Read at Chicago meeting, Amer. Astron. Soc. (1920); Pubs. Amer. Astron. Soc., 25th meeting, 225–226; Pop. Astron., vol. 29, 225–226 (1921).

———. Measurement of star diameters by the interferometer method. Read at April meeting, Amer. Philos. Soc. (1921); Proc. Amer. Phil. Soc., vol. 60 (1921).

———. The 100-inch Hooker reflecting telescope of the Mount Wilson Observatory. Armour Engineer, vol. 11, 307–316 (1920).

———. See Michelson, A. A.

Pearson, J. W. See Shipley, P. G.

Pennypacker, J. Y. See Harris, J. Arthur.

Pettit, Edison. Micrometric measures of double stars, made with the 12-inch refractor at the Washburn College Observatory. Astron. Jour., vol. 33, 150–153 (1921).

Powers, G. F. See Park, E. A.

Prigosen, R. E. The formation of vacuoles and neutral red granules in connective-tissue cells and blood-cells observed under abnormal conditions. Johns Hopkins Hosp. Bull., vol. 32, 206–211 (1921).

Reed, H. S. See Harris, J. Arthur.

Richards, Theodore W. Nobel lecture on atomic weights. Les Prix Nobel en 1914–1918, Stockholm, Imprimerie Royale (1921)

———, and Sylvester Boyer. Further studies concerning gallium. Jour. Amer. Chem. Soc., vol. 43, 274 (Feb. 1921).

———, and Emmett K. Carver. A critical study of the capillary rise method of determining surface tension, with data for water, benzene, toluene, chloroform, carbon tetrachloride, ether, and dimethyl aniline. Jour. Amer. Chem. Soc., vol. 43, 827 (Apr. 1921).

———, and Harold S. Davis. The heats of combustion of benzene, toluene, aliphatic alcohols, cyclophexanol, and other carbon compounds. Jour. Amer. Chem. Soc., vol. 42, 1599 (Aug. 1920).

———, and Henry Krepelka. A revision of the atomic weight of aluminum. The analysis of aluminum bromide. Preliminary paper. Jour. Amer. Chem. Soc., vol. 42, 2221 (Nov. 1920).

———, and Allan W. Rowe. An indirect method of determining the specific heat of dilute solutions, with preliminary data concerning hydrochloric acid. Jour. Amer. Chem. Soc., vol. 42, 1621 (Aug. 1920).

Richards, Theodore W., and Allan W. Rowe. The heats of dilution and the specific heats of dilute solutions of nitric acid and of hydroxides and chlorides and nitrates of lithium, sodium, potassium, and cesium. Jour. Amer. Chem. Soc., vol. 43, 770 (Apr. 1921).

Riddle, O. Calorimetric determinations of the energy in yolk-protein and yolk-fat of doves and pigeons. Science, n. s., vol. 51, 350 (1920).

———. Differential survival of male and female embryos in increased and decreased pressures of oxygen. Proc. Soc Exper. Biol. and Med., vol. 18, 88–91 (1920).

———. General effects of increased and decreased pressures of oxygen on dove embryos. Proc. Soc. Exper. Biol. and Med., vol. 18, 102–105 (1921).

———. Inadequate egg shells and the early death of embryos in the egg. Amer. Jour. Phys., vol. 57, 250–263 (1921).

———, and E. H. Behre. On the relation of stale sperm to fertility and sex in ring-doves. Amer. Jour. Phys., vol. 57, 228–249 (1921).

———, and M. C. Hanke. Effects of feeding soluble calcium salts upon reproductive secretions and upon the total inorganic constituents of the egg shell. Amer. Jour. Phys., vol. 57, 264–274 (1921).

———, and C. V. King. The relation of nerve stimuli to oviducal secretions as indicated by effects of atropine and other alkaloids. Amer. Jour. Phys., vol. 57, 275–290 (1921).

Ritchie, Mary. See Shapley, Harlow.

Roberts, H. S., and F. Hastings Smyth. The system copper : cupric oxide : oxygen. Jour. Amer. Chem. Soc., vol. 43, 1061–1079 (1921).

———. See Smyth, F. Hastings.

Rowe, Allan W. See Richards, Theodore W.

Russell, Henry Norris. Rubidium in the sun. Read at Berkeley meeting, A. S. P. (1921); Pubs. A. S. P., vol. 33, 202–204 (1921).

Sabin, F. R. Healing of end-to-end intestinal anastomoses, with special reference to the regeneration of blood-vessels. Johns Hopkins Hosp. Bull., vol. 31, 289–300 (1920).

Sanford, Roscoe F. The orbits of seven spectroscopic binaries. Astrophys. Jour., vol. 53, 201–223 (1921); Mt. Wilson Contr., No. 201.

———. Two stars of spectral class R with large radial velocities. Pubs. A. S. P., vol. 32, 278–279 (1920).

———. Note on the spectroscopic binary p Velorum. Pubs. A. S. P., vol. 33, 173–174 (1921).

Sarton, George. Synthetic bibliography with special reference to the history of science. Isis, vol. 3, 159–170 (1920).

———. Herbert Spencer (with bibliographical and iconographical notes). Isis, vol. 3, 375–390, portrait (1921).

———. Eighth critical bibliography of the history, philosophy, and organization of science and of the history of civilization (to April 1920). Isis, vol. 3, 316–371 (1920).

———. Ninth critical bibliography, etc. (to August 1920). Isis, vol. 4, 451–503 (1921).

———. Science and style. Scribner's Mag., vol. 69, 755–759 (June 1921).

———. Isis: International review devoted to the history of science and civilization (editor). Vol. 3, 157–570 (1920–1).

Schultz, A. H. Rassenunterschiede in der Entwicklung der Nase und in den Nasenkorpeln. Actes de la Soc. Helvetique des Sci. Natur. Neuchâtel (1920).

———. Observations on Colobus fetuses. Bull. Amer. Mus. Nat. Hist. (1921).

———. Sternal gland in orang-utan. Jour. Mammalogy (1921).

———. Observations on the Guiana howling monkey. Zoologica (1921).

Scofield, C. S. See Harris, J. Arthur.

Seares, Frederick H. Comparative tests of the 100-inch and 60-inch reflectors. Read at Chicago meeting, Amer. Astron. Soc. (1920); Pubs. Amer. Astron. Soc., 25th meeting, 229–230; Pop. Astron., vol. 29, 229–271 (1921).

———. See Adams, Walter S.

Shapley, Harlow. The scale of the universe. William Ellery Hale lecture, annual meeting, Nat. Acad. Sci. (1920); Bull. Nat. Research Council, No. 11 (1921).

———. Novæ and variable stars. Pubs. A. S. P., vol. 33, 185–194 (1921).

———. Note on changes in the period and light-curve of the cluster variable SW Andromedæ. Monthly Notices, vol. 81, 208–213 (1921).

———, and Helen Davis. Studies of magnitude in star clusters: XII. Summary of a photometric investigation of the globular system Messier 3. Proc. Nat. Acad. Sci., vol. 6, 486–489 (1920); Mt. Wilson Communications, No. 70.

———, and Mary Ritchie. Studies based on the colors and magnitudes in stellar clusters. 18th paper: The periods and light-curves of 26 Cepheid variables in Messier 72. Astrophys. Jour., vol. 52, 232–247 (1920); Mt. Wilson Contr., No. 195.

Shellshear, J. L. The presence of a head cavity in a human embryo of 4 mm. Anat. Rec., vol. 21, 81 (1921).

Shepherd, E. S. Kilauea gases, 1919. Bull. Hawaiian Volcano Observ., vol. 9, 83-88 (1921).

Sherman, H. C., and M. L. Caldwell. A study of the influence of arginine, histidine, tryptophane, and cystine upon the hydrolysis of starch by purified pancreatic amylase. Jour. Amer. Chem. Soc., vol. 43 (Sept. 1921).

———, and F. Walker. The influence of certain amino acids upon the enzymic hydrolysis of starch. Jour. Amer. Chem. Soc., vol. 43 (Sept. 1921).

———, and M. Wayman. Effect of certain antiseptics upon the activity of amylases. Jour. Amer. Chem. Soc., vol. 43 (Sept. 1921).

Shipley, P. G., J. W. Pearson, A. A. Weech, and C. H. Greene. X-ray pictures of the bones in the diagnosis of syphilis in the fetus and in young infants. Johns Hopkins Hosp. Bull., vol. 32, 75–77 (1921).

Sinnott, E. W. See Harris, J. Arthur.

Smith, D. T. The pigmented ephithelium of the embryo chick's eye studied *in vivo* and *in vitro*. Johns Hopkins Hosp. Bull., vol. 31, 239–246 (1920).

———. The ingestion of melanin pigment granules by tissue-culture cells grown from the embryo chick in Locke-Lewis solution. Anat. Rec., vol. 21, 82 (1920).

———. The ingestion of melanin pigment granules by tissue-cultures. Johns Hopkins Hosp. Bull., vol. 32, 240–244 (1921).

Smyth, F. Hastings, and Howard S. Roberts. The system cupric oxide, cuprous oxide, oxygen. Jour. Amer. Chem. Soc., vol. 42, 2582–2607 (1920).

———. See Roberts, H. S.

Solberg, H. See Bjerknes, J.

Sosman, Robert B. An outline of geophysical-chemical problems. Proc. Nat. Acad. Sci., vol. 6, 592–601 (1920).

———. The distribution of scientific information in the United States. Jour. Wash. Acad. Sci., vol. 11, 69–99 (1921).

St. John, Charles E. The displacement of solar lines. Nature, vol. 106, 789–790 (1921).

———. The spectroscopic committee of the Division of Physical Sciences of the Nationa Research Council. Phys. Rev., vol. 16, 372–374 (1920).

———, and Harold D. Babcock. Wave-lengths of lines in the iron arc from grating and interferometer measures, λ3370–λ6750. Astrophys. Jour., vol. 53, 260–299 (1921); Mt. Wilson Contr., No. 202.

———, and Seth B. Nicholson. On systematic displacements of lines in spectra of Venus. Astrophys. Jour., vol. 53, 380–391 (1921); Mt. Wilson Contr., No. 208.

———, ———. Determination of the solar parallax from spectroscopic observations of Venus. Pubs. A. S. P., vol. 32, 332–334 (1920).

———, ———. On the absence of selective absorption in the atmosphere of Venus. Read at Berkeley meeting, A. S. P. (1921); Pubs. A. S. P., vol. 33, 208–209 (1921).

Streeter, George L. Migration of the ear vesicle in the tadpole during normal development. Anat. Rec., vol. 21, 115–126 (1921).

———. A well-preserved human embryo of the presomite period. Anat. Rec., vol. 21, 68 (1921).

Strömberg, Gustaf. Uppmätning af dubbelstjarnor med användande av ljusets interferens. Nordisk Astronomisk Tidsskrift, vol. 1, 122–125 (1920).

———. See Adams, Walter S.

Strong, L. C., and C. C. Little. Tests for physiological differences in transplantable tumors. Proc. Soc. Exper. Biol. and Med., vol. 18, 45–48 (1920).

Summary of Mount Wilson magnetic observations of sun-spots, July, 1920–June, 1921. Pubs. A. S. P., vol. 32, 279–281, 337–339 (1920); vol. 33, 57–59, 116–118, 179–181, 209–211 (1921).

Valentine, A. T. See Harris, J. Arthur.

van Maanen, Adriaan. Internal motion in the spiral nebula Messier 33. Proc. Nat. Acad. Sci., vol. 7, 1–5 (1921); Mt. Wilson Communications, No. 71.

———. Parallaxes of two Cepheids. Pubs. A. S. P., vol. 32, 335 (1920).

———. Parallax of a faint star with large proper motion. Pubs. A. S. P., vol. 32, 335 (1920).

———. The parallax of N. G. C. 226. Pubs. A. S. P., vol. 33, 110–111 (1921).

———. Internal motion in four spiral nebulæ. Read at Berkeley meeting, A. S. P., vol. 33, 200–202 (1921); read at Middletown meeting, Amer. Astron. Soc. (1921).

———. Bewegung in den Spiral-nebel M33 Trianguli. Physica, vol. 1, 125–127 (1921).

———. The parallaxes of two long-period variables. Pubs. A. S. P., vol. 33, 111 (1921).

Varnum, William B. On differential horizontal refraction. Astron. Jour., No. 787 (May 1921).

Vaughan, T. W. Corals and the formation of coral reefs. Smithsonian Rept. for 1917, 189–276, 37 pls. (1919).

Vicari, E. M. See MacDowell, E. C.

Walker, F. See Sherman, H. C.

Wayman, M. See Sherman, H. C.

Warner, D. E. See Harris, J. Arthur.

Washington, H. S. Le rioliti di Lipari. Boll. Soc. Geol. Ital., vol. 39, 141–159 (1920).

———. The chemistry of the earth's crust. Jour. Franklin Inst., vol. 190, 757–815 (1920) (Reprinted, Smithsonian Misc. Coll., 1921).

———. A meteor fall in the Atlantic. Science, n. s., vol. 53, 90–91 (1921).

———. The problems of volcanology. Proc. Nat. Acad. Sci., vol. 6, 583–591 (1920).

———. Note on crucibles used in rock analysis. Jour. Wash. Acad. Sci., vol. 11, 9–13 (1921).

———. Aphthitalite from Kilauea. Amer. Mineral., vol. 6, 121–125 (1921).

———, and H. E. Merwin. Note on augite from Vesuvius and Etna. Amer. Jour. Sci., vol. 1, 20–30 (1921).

Webster, L. T. See Lewis, W. H.

Weech, A. A. See Shipley, P. G.

Weed, L. H. The cells of the arachnoid. Johns Hopkins Hosp. Bull., vol. 31, 343–350 (1921).

———, and Walter Hughson. The skull as a closed box. Anat. Rec., vol. 21, p. 88 (1921).

Wesson, M. B. Anatomical, embryological, and physiological studies of the trigone and neck of the bladder. Jour. Urol., vol. 4, 279–315 (1920).

———. See Young, H. H.

White, W. P. Unification of symbols and diagrams. Science, n. s., vol. 51, 414–417 (1920).

———. The latent heats of fusion of nickel and monel metal. Chem. and Met. Eng., vol. 25, 17–21 (1921).

Wieland, George R. Recedent lake shores of the Cretaceous. Science, n. s., vol. 52, 537–538 (Dec. 3, 1920).

———. Monocarpy and pseudomonocarpy in the Cycadeoids. Amer. Jour. Bot., vol. 8, 218–230, pls. ix-xii (Apr. 1921).

———. Paleobotany as viewed by two geologists. Science, n. s., vol. 53, 437–439 (May 6, 1921).

———. Two new North American Cycadeoids. Can. Geol. Survey, Bull. No. 33, 79–85, pls. ix-xii (Sept. 14, 1921).

Wilber, D. T. See Nichols, E. L.

Williams, J. W. A critical analysis of twenty-one years' experience with Cæsarean section. Johns Hopkins Hosp. Bull. vol. 32, 173–184 (1921).

Williamson, E. D. See Adams, L. H.

Wilson, Ralph W. Orbit of β Doradus. (Abstract) Pop. Astron., vol. 29 (Feb. 1921).

———. On the period eccentricity relation in binary systems. Astron. Jour., No. 786 (May 1921).

———, and C. M. Huffer. Orbit of l Carinæ. (Abstract) Pop. Astron. vol. 29 (Feb. 1921).

———, ———. Orbit of θ Sagittarii. (Abstract) Pop. Astron., vol. 29 (Feb. 1921).

Wislocki, G. B. The fate of true solutions (phenolsulphonephthalein) and colloids (trypan blue) injected into the mammalian embryo. Johns Hopkins Hosp. Bull., vol. 32, 93–96 (1921).

———. Experimental observations on bone-marrow. Johns Hopkins Hosp. Bull., vol. 32, 132–134 (1921).

———. Observations upon the behavior of carbon granules injected into pregnant animals. Anat. Rec., vol. 21, 29–33 (1921).

Wright, Fred. E. War-time production of optical munitions. (Papers on Optical Glass, No. 33.) Army Ordnance, vol. 1, 247–251 (1921).

———. The angular deflections produced on transmitted light rays by slightly incorrect interfacial angles of reflection prisms. (Papers on Optical Glass, No. 34.) Jour. Opt. Soc. Amer., vol. 5, 193–204 (1921).

———. Cords and surface-markings in glassware. (Papers on Optical Glass, No. 35.) Jour. Amer. Ceram. Soc., vol. 4, 655–661 (1921).

———. Note on the determination of the relative expansion of glasses. (Papers on Optical Glass, No. 36.) Jour. Opt. Soc. Amer., vol. 5, 453–460 (1921).

———. On tracing rays of light through a reflecting prism with the aid of a meridian projection plot. (Papers on Optical Glass, No. 37.) Jour. Opt. Soc. Amer., vol. 5, 410–419 (1921).

———. Dispersion in optical glasses: III. (Papers on Optical Glass, No. 38.) Jour. Opt. Soc. Amer., vol. 5, 389–397 (1921).

———. The manufacture of optical glass and of optical systems: A war-time problem. (Papers on Optical Glass, No. 40.) Ordnance Dept. Doc. No. 2037, 309, 94 illus. (1921).

Wyckoff, Ralph W. G. An outline of the application of the theory of space groups to the study of the structure of crystals. Amer. Jour. Sci., vol. 1, 127–137 (1921).

———. The crystal structure of magnesium oxide. Amer. Jour. Sci., vol. 1, 138–152 (1921).

———. The determination of the structure of crystals. Jour. Franklin Inst., vol. 191, 199–230 (1921). Reprinted, Smithsonian Misc. Coll. (1921).

———. The wave-lengths of X-rays. Jour. Wash. Acad. Sci., vol. 11, 366–373 (1921).

———. The crystal structure of alabandite (MnS). Amer. Jour. Sci., vol. 2, 239–249 (1921).

Young, H. H., and M. B. Wesson. The anatomy and surgery of the trigon. Arch. Surg., vol. 3, 1–37 (1921).

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1921.

During this year the Executive Committee held nine meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 10, 1920, the members of the Executive Committee met and organized by the re-election of Mr. Walcott as Chairman for 1921, and by voting that the Administrative Secretary of the Institution act as secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1920–1921, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and an outline of suggested appropriations for the year 1922. The Executive Committee hereby approves the report and recommendations of the President, upon the basis of which additional recommendations respecting appropriations for the year 1922 were authorized by the Committee at its meetings of November.

The Board of Trustees, at its meeting of December 10, 1920, appointed Messrs. Price, Waterhouse & Co., of New York, to audit the accounts of the Institution for the fiscal year ending October 31, 1921. The report of the auditor, including a balance-sheet showing the assets and liabilities of the Institution on October 31, 1921, is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

It is reported that Messrs. Howe, Swayze and Bradley, of Washington, D. C., have been appointed local attorneys of the Institution, under the general direction of Messrs. Cadwalader, Wickersham and Taft, Counsel of the Institution, for the submission of opinion on questions which it may not be essential to refer to counsel.

The Executive Committee begs to recommend, with concurrence of the Chairman of the Finance Committee, that the American Audit Company be appointed to audit the accounts of the Institution for the fiscal year ending October 31, 1922.

At the meeting of the Executive Committee of May 13, 1921, the following resolutions were passed, and these recommendations have been effective in the preparation of a budget of the Institution for 1922:

Resolved, That the income of the Colburn Fund which may accrue on and after January 1, 1922, shall be regarded as available for appropriation.

Resolved, That the Executive Committee recommend to the Board of Trustees, at its annual meeting in December 1921, that appropriations on account of the Insurance Fund be continued, beginning with the year 1922, in such amounts as may be sufficient, together with the estimated income on this Fund, to total $25,000 annually, said total to be added to the principal of the Fund until otherwise ordered.

It may be noted especially that the Executive Committee considers it desirable that special designation of the source of income shall be given in connection with any future allotments which may be made on account of the income of the Colburn Fund.

No vacancies exist in the membership of the Board of Trustees. The tenure of service of the following officers of the Board of Trustees will expire at the annual meeting on December 9: Mr. Root as Chairman of the Board; Mr. Walcott as Vice-Chairman; Mr. Dodge as Secretary; Messrs. Parsons, Paton, and Pritchett as members of the Executive Committee; Messrs. Dodge, Pritchett, and Wickersham as members of the Finance Committee; and Messrs. Brookings, Hutchinson, and Wickersham as members of the Auditing Committee.

CHARLES D. WALCOTT, *Chairman.*
CLEVELAND H. DODGE.
JOHN C. MERRIAM.
WM. BARCLAY PARSONS.
STEWART PATON.
HENRY S. PRITCHETT.
ELIHU ROOT.
HENRY WHITE.

November 15, 1921.

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1921.

RECEIPTS.		
Interest:		
Endowment	a $16,815,544.74	
Reserve Fund (Cr. to R. F.)	631,661.31	
Reserve Fund (Cr. to Income)	119,235.49	
Insurance	79,485.54	
Colburn Fund	25,169.08	
Pension	11,365.69	
		$17,682,461.85
Colburn Fund		52,015.74
Sales of Publications:		
Index Medicus	80,029.51	
Year Book	1,118.26	
Miscellaneous	105,118.65	
		186,266.42
Revertments:		
Grants and Unallotted Publication	171,206.95	
Administration	11,081.53	
Unappropriated Fund	22,001.99	
		204,290.47
Miscellaneous:		
Carnegie Corporation of N. Y. C. I. of W. $750,000 Nat'l R. C. 150,000	900,000.00	
Insurance	5,259.95	
Pension Fund	3,588.97	
Sale of paper	6,521.12	
		915,370.04
Redemption and Sale of Bonds		1,445,609.37
		20,486,013.89

DISBURSEMENTS.		
Investment:		
Securities	$5,077,790.38	
Collection charges	8,582.15	
Administration Building and Site	309,915.69	
		$5,396,288.22
Pension Fund		55,337.29
Insurance		22,270.94
Grants:		
Large	10,565,303.41	
Minor	2,089,004.24	
		12,654,307.65
Publication		b 934,698.11
National Research Council		150,000.00
Administration:		
Trustees	d 51,584.83	
Executive Committee	32,357.38	
Advisory Committees:		
Honoraria 1902–1907	11,860.00	
Travel and subsistence	4,367.41	
Salaries	552,934.15	
Shipping publications	56,567.24	
Rent, surety, telephone	33,076.12	
Equipment	17,192.70	
Postage, express	23,558.80	
Printing	bc 61,580.63	
Office expenses	31,005.74	
Contingent	504.33	
Building and grounds:		
Supplies, janitor	30,922.65	
Fuel, light, water	12,754.00	
Organization expenses (1902)	6,991.98	
		927,257.96
		20,140,160.17
Cash in Banks		345,853.72
		20,486,013.89

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[a] Including interest from Income and Building Fund bonds.

[b] Year Books and shipping publications carried under Administration to January 1, 1921, and thereafter under Publication.

[c] Including Year Books published prior to January, 1921.

[d] Travel and subsistence in connection with official meetings.

REPORT OF AUDITORS.

New York, *November 19, 1921.*

To the Board of Trustees,
Carnegie Institution of Washington,
Washington, D. C.

Dear Sirs: We beg to report that we have audited the accounts of the Institution for the year ended October 31, 1921.

The securities representing the investments have been exhibited to us, and we have ascertained that the income therefrom has been duly accounted for. We counted the cash on hand and verified the cash in bank with certificates from the depositaries.

Cancelled checks have been exhibited to us for all payments made during the period by the administrative office at Washington, and we have tested these payments with properly approved vouchers.

The books of the various departments were not audited by us, as these departments are audited by the bursar under authority of the Executive Committee.

The appropriations and allotments were checked with certified copies of the minutes of the Trustees and of the Executive Committee.

In accordance with the established practice of the Institution, real estate and equipment are carried at the original outlay, and all publications on hand at their selling value, and both the unexpended appropriations and the balance of income receivable for the calendar year are taken up in the balance sheet of October 31, 1921. Securities owned are carried at original valuation or cost.

Subject to the foregoing explanation, we certify that the statements printed on pages 35 to 40 of the Year Book for 1921 are in accordance with the books of the Institution and are correct.

We found the books to be accurately and carefully kept, and every facility was afforded us during the course of our audit.

Yours very truly,

(Signed) Price, Waterhouse & Co.

Balance Sheet, October 31, 1921.

ASSETS.

Investments (interest-bearing securities):			
Endowment		$22,119,722.55	
Colburn Fund		100,182.97	
Reserve Fund		3,097,774.44	
Insurance Fund		318,325.74	
Harriman Fund		300,000.00	
Pension Fund		103,532.41	
		26,039,538.11	
Cash awaiting investment		45,392.80	
			$26,084,930.91
Property Account:			
Real Estate and Equipment at original cost—			
Division of Administration		339,001.47	
Departments of Research		2,790,907.36	
			3,129,908.83
			29,214,839.74
Current Assets:			
Cash—			
In banks (investment accounts)	$300,460.92		
Cash and stamps	300.00		
	300,760.92		
Income Receivable as estimated for the year 1921—			
Balance uncollected	142,473.36		
		443,234.28	
Publications and Paper—			
Books on hand at sale price	304,371.00		
Printing paper in stock	17,723.52		
	322,094.52		
Outstanding Accounts—			
Sundry bills for publications sold	2,744.54		
		324,839.06	
			768,073.34
			29,982,913.08

LIABILITIES.

Endowment and Other Funds:			
Endowment		$22,120,000.00	
Colburn Fund		103,002.41	
Reserve Fund		3,099,543.62	
Insurance Fund		343,790.00	
Pension Fund		118,594.88	
Harriman Fund		300,000.00	
			$26,084,930.91
Income Invested in Property			3,129,908.83
			29,214,839.74
Current Liabilities:			
Large Grants	$185,676.13		
Minor Grants	63,909.45		
Publications	59,164.60		
Administration	13,915.21		
		322,665.39	
Unappropriated Balance		120,568.89	
Value of Publications, Paper, and Invoices		324,839.06	
			768,073.34
			29,982,913.08

Receipts and Disbursements for the Year Ending October 31, 1921.

RECEIPTS.		
Interest from:		
Endowment—		
Bonds	$1,112,441.25	
Bank balance	7,389.20	$1,119,830.45
Reserve Fund—		
Bonds (Cr. of R. F.)	19,371.43	
Bonds (Cr. of Income a/c)	119,011.09	
Bank balance	224.40	138,606.92
Insurance Fund—		
Bonds	13,452.33	
Bank balance	543.13	13,995.46
Colburn Fund—		
Bonds	4,995.32	
Bank balance	45.29	5,040.61
Pension Fund—		
Bonds	4,741.20	
Bank balance	437.83	5,179.03
Sales of Publications:		
Index Medicus	6,277.32	
Year Book	50.55	
Miscellaneous books	10,356.64	16,684.51
Revertments:		
Grants and Unallotted, Publication	4,068.69	
Unappropriated Fund	6,569.90	
Administration	400.00	11,038.59
Redemption and Sale of Bonds		50,000.00
Miscellaneous:		
Carnegie Corp. of N. Y.	150,000.00	
Pension Fund	3,362.97	
Insurance Fund	117.94	
Sale of paper	68.15	153,549.06
		1,513,924.63
Balance, Oct. 31, 1920		234,519.46
		1,748,444.09

DISBURSEMENTS.		
Investment:		
Securities	$107,620.86	
Collection charges	1,769.39	$109,390.25
Pension Fund:		
Annuity contribution		31,696.27
Grants:		
Large	981,186.46	
Minor	140,198.95	1,121,385.41
Publication:		
General Publication	58,890.51	
Division of Publications	9,775.47	
Shipping Expenses	6,008.48	
Year Book, Catalogues, etc	6,713.87	81,388.33
Administration:		
Trustees	3,594.97	
Executive Committee	1,655.34	
Salaries	40,805.00	
Shipping publications	1,604.08	
Surety, rent, telephone	683.06	
Equipment	887.11	
Postage, express	656.27	
Printing, paper	1,630.61	
Office, petty expense, stationery	1,845.31	
Contingent	504.33	
Building and grounds—		
Supplies, janitors	2,767.98	
Fuel, light, water	2,096.05	58,730.11
		1,402,590.37
Cash in banks		345,853.72
		1,748,444.09

Schedule of Securities.

Par Value.	SECURITIES.	Investment Value.	Total.
	Endowment.		
$21,200,000	U. S. Steel Corporation, Registered 50-year 5% Gold Bonds, Series A, B, C, D, E, F, due April 1, 1951	$21,200,000.00	
175,000	Chicago, Milwaukee & Puget Sound Railway Company, First Mortgage 4% Gold Bonds, due January 1, 1949	159,268.00	
14,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	13,953.75	
325,000	Lehigh & Lake Erie Railroad Company, First Mortgage 4½% 50-year Gold Bonds, due March 1, 1957	331,568.30	
237,000	New York City 4½% Registered Bonds, due March 1, 1963	253,557.50	
150,000	South & North Alabama Railroad Company, Consolidated Mortgage 5% Bonds, due August 1, 1936	160,875.00	
500	United States of America Third Liberty Loan	500.00	
			$22,119,722.55
	Colburn Fund.		
20,000	Acker, Merrall and Condit Company, Debenture 6% Bonds	13,600.00	
4,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage, 4½% Bonds, due 1989	4,070.00	
8,000	Park and Tilford Company, Sinking Fund, Debenture 6% Bonds	6,400.00	
50,000	Pennsylvania Railroad Co., General Mortgage, 4½% Bonds, due June 1, 1965	51,062.50	
42,000	Pittsburg, Shawmut & Northern Railroad, First Mortgage, 4% Bonds, due February 1, 1952	4,200.00	
10,650	United States of America Second Liberty Loan Converted 4¼s	9,922.67	
5,500	United States of America Third Liberty Loan of 1918	5,291.16	
3,100	United States of America Fourth Liberty Loan of 1918	3,036.64	
2,600	United States of America Victory Liberty Loan of 1919	2,600.00	
			100,182.97
	Harriman Fund.		
100,000	Southern Pacific Company, San Francisco Terminal, First Mortgage 4% Bonds, due 1950	100,000.00	
200,000	Chicago, Burlington & Quincy R. R. Co., Illinois Division, 4% Bonds, due 1949	200,000.00	
			300,000.00
22,547,350	*Carried forward*		22,519,905.52

Schedule of Securities—continued.

Par Value.	SECURITIES.	Investment Value.	Total.
$22,547,350	............*Brought forward*............................		$22,519,905.52
	Insurance Fund.		
28,000	American Telephone & Telegraph Company, 4½% Convertible Bonds................	$28,978.00	
50,000	Atchison, Topeka & Santa Fe Railway Company, General Mortgage, 100-year, 4% Registered Gold Bonds, due 1995........	50,056.25	
25,000	Bell Telephone Company of Canada, Debenture 5% Bonds, due April 1, 1925.......	24,760.00	
30,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage, 4% Bonds, due March 1, 1958.....................	28,237.50	
1,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989...............	995.00	
21,000	Great Northern Railway First and Refunding 4¼% Bonds, due 1961.................	20,944.00	
21,000	Illinois Central Railroad Company, Refunding Mortgage 4% Bonds, due November 1, 1955.................................	19,008.75	
24,000	Pennsylvania Railroad Company, Consolidated Mortgage, 4½% Bonds, due Aug. 1, 1960.................................	25,095.01	
26,700	United States of America Second Liberty Loan Converted 4¼s..................	23,722.33	
63,500	United States of America Third Liberty Loan of 1918.........................	61,128.90	
3,000	United States of America Fourth Liberty Loan of 1918.........................	3,000.00	
32,400	United States of America Victory Liberty Loan of 1919.........................	32,400.00	
			318,325.74
	Reserve Fund.		
50,000	American Telephone & Telegraph Company, Collateral Trust 4% Bonds, due 1929.....	$45,500.00	
96,000	American Telephone & Telegraph Company, 4½% Convertible Bonds.............	99,456.25	
100,000	Baltimore & Ohio Railroad Company, General and Refunding 5% Bonds, due 1995..	102,375.00	
50,000	Central Pacific Railway Company, First Refunding Mortgage 4% Registered Gold Bonds, due 1949......................	48,250.00	
150,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage, 4% Bonds, due March 1st, 1958......................	141,263.75	
15,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989...............	14,925.00	
120,000	Chicago and North-Western General Mortgage 3½% Bonds, due November 1, 1987..	100,300.00	
155,000	General Electric, 5% Gold Debenture Bonds	158,213.47	
48,000	Great Northern Railway Company, First and Refunding Mortgage 4¼% Bonds, due 1961.................................	48,109.25	
100,000	Illinois Central Railroad Company, Refunding 4% Bonds, due 1955................	89,668.75	
280,000	Interborough Rapid Transit Company, First Refunding Mortgage 5% Bonds, due 1966	276,701.00	
24,036,950	............*Carried forward*.............	1,124,762.47	22,838,231.26

Schedule of Securities—continued.

Par Value.	SECURITIES.	Investment Value.	Total.
$24,036,950	............*Brought forward*..............	$1,124,762.47	$22,838,231.26
	Reserve Fund—continued.		
50,000	Lake Shore & Michigan Southern Railway Company, Registered 25-year 4% Gold Bonds, due September 1, 1928...........	47,000.00	
50,000	Long Island Railroad Company, Refunding Mortgage 4% Bonds, due 1949..........	48,285.00	
50,000	New York, Westchester & Boston Railway Company, First Mortgage 4½% Bonds, due 1946............................	49,187.50	
50,000	Northern Pacific-Great Northern, Convertible 6½% Bonds, due 1936..............	48,250.00	
50,000	Northern Pacific Railway Co., General Lien Railway and Land Grant 3% Bonds, due Jan. 1, 2047.........................	33,101.25	
50,000	Oregon-Washington Railroad & Navigation Company, First and Refunding 4% Mortgage Bonds, due 1961..................	46,375.00	
30,000	Pennsylvania Railroad Company, General Mortgage 4½% Bonds, due June 1, 1965..	29,837.50	
101,000	Pennsylvania Railroad Company, Consolidated Mortgage, 4½% Bonds, due Aug. 1, 1960.................................	105,608.12	
100,000	Southern Pacific Railroad First Refunding Mortgage, 4% Bonds, due 1955.........	92,148.75	
140,000	Union Pacific Railroad Co. First Lien and Refunding 4% Bonds, due June 1, 2008...	128,722.50	
112,500	United States Liberty Loan—1st Converted 4¼s, due 1947.......................	112,500.00	
384,300	United States of America Liberty Loan of 1917—2nd Converted..................	349,286.85	
419,500	United States of America Third Liberty Loan of 1918..........................	404,728.20	
364,000	United States of America Fourth Liberty Loan of 1918..........................	357,181.30	
120,800	United States of America Victory Liberty Loan of 1919.........................	120,800.00	
			3,097,774.44
	Pension Fund.		
50,000	United States of America Victory Liberty Loan of 1919.........................	50,000.00	
61,350	United States of America Second Liberty Loan Converted 4¼s..................	53,532.41	
			103,532.41
26,220,400			26,039,538.11

Real Estate and Equipment, Original Cost.

Administration:		
Building, site, and equipment		$339,001.47
Department of Botanical Research (September 30, 1921):		
Buildings and grounds	$52,173.37	
Laboratory and library	24,321.43	
Operating appliances	11,970.81	
		88,465.61
Department of Embryology (September 30, 1921):		
Laboratory and office		11,982.95
Department of Genetics (September 30, 1921):		
Buildings, grounds, field	264,901.36	
Operating	11,024.98	
Laboratory apparatus	12,710.62	
Library	20,098.98	
Archives	45,835.67	
		354,571.61
Geophysical Laboratory (September 30, 1921):		
Building, library, operating appliances	181,589.18	
Laboratory apparatus	82,927.04	
Shop equipment	10,948.36	
		275,464.58
Department of Historical Research (September 30, 1921):		
Office	2,790.02	
Library	4,158.00	
		6,948.02
Department of Marine Biology (September 30, 1921):		
Vessels	30,930.43	
Buildings, docks, furniture, and library	12,130.86	
Apparatus and instruments	9,122.55	
		52,183.84
Department of Meridian Astrometry (September 30, 1921):		
Apparatus and instruments	2,723.91	
Operating	3,862.69	
		6,586.60
Nutrition Laboratory (September 30, 1921):		
Building, office, and shop	121,859.32	
Laboratory apparatus	25,593.80	
		147,453.12
Mount Wilson Observatory (August 31, 1921):		
Buildings, grounds, road, and telephone line	191,874.12	
Shop equipment	39,182.89	
Instruments	462,351.14	
Furniture and operating appliances	138,845.16	
Hooker 100-inch reflector	572,263.91	
		1,404,517.22
Department of Terrestrial Magnetism (September 30, 1921):		
Building, site, and office	194,982.89	
Vessel and survey equipment	155,262.86	
Instruments, laboratory, and shop equipment	92,488.06	
		442,733.81
		3,129,908.83

REPORTS ON INVESTIGATIONS AND PROJECTS

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1921, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.[1]

D. T. MacDougal, Director.

The investigations carried on by this Department have been confined to the main fields of research, to which attention has been devoted for several years.

The study of growth has led to a consideration of the phenomena of imbibition and osmosis in protoplasm. The detailed action of biocolloidal mixtures, living and dead cell-masses, and the changes in volume of living plants of various types have been measured with great accuracy by newly designed apparatuses, including the auxograph, the dendrograph, and a new type of colloidal cell.

The study of photosynthesis in the green cells of living plants and carbohydrate metabolism in general has made such progress as is possible in this complex and difficult subject. A small laboratory especially designed for this work has been completed within the year at Carmel, California. The equable temperatures of the region and the constant-temperature chambers provided in this structure are features of great value in such investigations.

Researches on nutrition and metabolism have been devoted to the phase of the subject in which sources of nitrogen, acidity, and balance of the nutrient salts have been considered, while some attention has been devoted to the sources of the vitamins and their action in the organisms in which they originate.

Studies in the development of root-systems have been carried through to extensive, detailed, and accurate measurement of the effect of soil-atmospheres upon the growth of roots. The rarer elements of the atmosphere, helium and argon, have been used for the first time as the neutral element in mixtures of atmospheric gases in the place of nitrogen.

The composition and behavior of the elements of the flora in a desert area have been found to depend largely upon such soil conditions as salt-content, course of temperature, and mechanical texture of the soil.

The examination of the vegetation of the more arid regions, as part of the original purpose of the Desert Laboratory, has already included field work in western America, Mexico, South Australia, and northern Africa, and a party is now carrying out field work in South Africa in coöperation with the Division of Botany of the Union of South Africa.

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[1] Situated at Tucson, Arizona, and Carmel, California.

GROWTH AND HYDRATION.

Growth in Trees, by D. T. MacDougal.

The changes in volume of trunks of diverse types of trees, deciduous and evergreen coniferous types native to the Atlantic seaboard, the Mississippi Valley, various elevations in the Rocky Mountains, the plateau, mountain slopes, and desert valleys of Arizona, the plains of southern California, and the coastal region at Carmel, have been measured for several years as a part of a comprehensive research upon the fundamental physical factors in growth. An improved type of the newly designed dendrograph described in Publication No. 307 has been used and the following generalizations upon the basis of information acquired have been established:

1. The period in which enlargement of trunks takes place is comparatively brief, even in places in which the season is of indeterminate duration.

2. Growth is an activity of an embryogenic tract of tissue, which depends upon environmental conditions, and no part of the observations suggested a seasonal rhythmic action. The Chihuahua pine, which exhibits growth of the trunk with that of the branches on the dry mountain slopes in the advance of the temperatures in May and June, is brought to rest coincident with the desiccation of the soil in the dry fore-summer. Reawakening ensues consequent upon the summer rains and enlargement continues until checked by the decreasing temperatures and increased soil desiccation in the autumn. The Monterey pine (*Pinus radiata*) shows beginning growth of the trunks with the advance of temperatures, January to April, and comes to rest in July with the desiccation of the soil. *Quercus agrifolia* in the same region begins earlier and ceases to grow in June or July. Both may be awakened in July or August by deep irrigation of the soil.

3. The trunks of all the trees measured show a daily variation in size, by which the maximum is reached shortly after sunrise and the minimum at a time after noon dependent upon external agencies. These variations appear to depend upon the water-balance in the woody cylinder, are greatest in the seasons in which water-loss from the crown is greatest, are least in the seasons of lower temperatures and high humidities, and are to be detected in the records even in the period of most rapid enlargement of the trunk.

4. Measurement of variations in the woody cylinder were taken by arranging the contact rods of the dendrograph to bear on the wood formed by the tree two years previously. Thus in 1920, holes were bored through the wood of that year and of 1919 and contacts made at the bottom of the cavities.

5. In general, the awakening and growth of the terminal buds, with resultant elongation of leaders and branches, begin in many

trees some time before enlargement of the trunk takes place. The period separating the two may be no more than a week in *Quercus agrifolia* and has been seen to be as much as 10 or 12 weeks in *Pinus radiata*. Observations on the Parry spruce and Douglas fir show that the trunks of these trees are enlarging at a time when the buds are in a very early stage of enlargement.

6. In the single case in which dendrographs were attached to a pine tree 1 meter and 8 meters above the ground, growth began coincidentally at the two places in 1920. In the following year, however, the dendrograph at the higher point on the trunk recorded enlargement a few days before any action near the ground was made visible. In February 1921 an auxograph was brought into bearing on the internode of a pine tree 5 or 6 years old which had been formed in 1919. The buds had made a growth of 4 or 5 cm., but no action had begun in the internode. A second instrument was brought into bearing on the middle of the internode formed in 1920 on another young tree. Steady enlargement was in progress.

7. The embryonic layer of a tree is in the form of an inclosing sheath terminating in the cones of the growing points. Activation of this tract is generally initiated in the growing points. Swelling in the cambium layer may be practically coincident with this awakening in some trees. Cases are recorded in which weeks elapsed between the awakening of the buds and the enlargement of the base of the trunk. Activation of the growing cells may be taken to depend upon the localized food-supply, temperature, moisture, or other factors.

8. Estimates of the range of daily equalizing variations in a Monterey pine, taken from bearings on a thin layer of cork external to the bast of a trunk which had ceased to grow for the season, show that the diameter might vary 1 part in 1,750. That a large share of this variation is due to changes in the hydration of the living cells is proved by the fact that when bearings are taken on the woody cylinder of the trunk internal to the growing layer the variation drops to 1 part in 8,750 of the diameter. The actual change in volume, in the first instance calculated on the basis of a conical trunk 18 meters high and 35 cm. in diameter at the base, would amount to about 400 cu. cm., of which not more than one-fifth is attributable to variations in the wood. It is to be noted, however, that the change in the volume of the wood may by no means be taken to represent the water-deficit in the wood. The woody mass is made up of box-like cells, which may include a bubble of gas, the water forming no more than a thin film on the wall of the cell and inclosing the gas bubble in the condition of extreme water-deficit. The withdrawal of water through the walls of the cells, which are semi-rigid, increases the surface tension of the gas bubble, which results in a slight lessening of volume of the whole mass, but in an amount that would constitute no more than a small

fraction of the total of the water-loss. The trunk of a tree may be compared to the supply-hose of a fire-engine coupled to a hydrant. When the pressure from the mains is enough to supply water faster than it can be pumped out, the hose is distended. When the engine takes water faster than it can be delivered by the system, the hose collapses.

9. The greatest daily equalizing variations were shown by *Fraxinus*, *Pinus*, *Picea*, *Pseudotsuga*, and *Juglans*, and lesser variations were displayed by *Populus*, *Platanus*, *Fagus*, *Quercus*, and *Citrus*. No available facts furnish the basis of an adequate explanation of such differences.

10. Of 15 trees which were under dendrographic measurement in 1920, one each of *Pinus scopulorum*, *Citrus aurantica*, and *Parkinsonia microphylla* made no enlargement during the year. Such occurrences are to be taken into account in estimations of the ages of trees from the annual layers. Of the 12 trees under observation in 1921, only one, a small Monterey pine, showed no enlargement under the dendrograph.

11. The final effect of rainfall shown within a few hours is to accelerate growth, but it has been repeatedly observed that actual shrinkage may take place while the rain is falling. This action can not be traced to any instrumental error.

12. Irrigation of the soil which had a moisture-content of less than 6 per cent around the roots of a Monterey pine was followed within 24 hours by progressive enlargement, constituting growth at the base of the tree and at a point 8 meters higher. The distance from the absorbing surfaces of the roots through which the added water-supply must enter could not be less than 3 meters from the lower instrument, and within the day the influence of the added supply was felt at the upper instrument, 11 meters from the absorbing surfaces. It does not seem possible that water could have been conducted through the tracheids this distance within the given length of time.

13. An irrigation test similar to the above was made with a small California live oak (*Quercus agrifolia*). The results were even more startling than those described for the pine. Within 2 hours the dendrograph, which had its contacts with the tree at least 3 meters from the absorbing surfaces, showed some enlargement, an action which may be directly connected with the fact that the vessels in this oak are numerous and large.

14. The irrigation experiments might be held to simulate the effects of stream overflow, which if due to melting snows would not be accompanied by any marked higher humidity. It was seen to result in the formation of a tapering shell of wood, which was as thick as the seasonal formation at the base of the trunk, but which had only half this thickness 8 meters higher up on the trunk. The layer of normal formation was of practically identical thickness at the two places.

A New High-Temperature Record for Growth, by D. T. MacDougal and Earl B. Working.

A record of growth of young joints of a prickly pear (*Opuntia*) at 50° C. and 51.5° C. and of the active elongation of etiolated stems of the same plant growing at 49° C. was published in 1917 by MacDougal. Dr. J. M. McGee had found previously that the mature joints of the same *Opuntia* might reach temperatures of 55° C. in the open without damage, which was a record for endurance of the higher plants in air at the Desert Laboratory. In the repetition of the growth measurements at the Desert Laboratory late in March and April 1921, young joints which might reach temperatures of 49° C. in the sun in an unventilated glass house were heated further by the use of electric grills. Temperatures were taken by mercurial thermometers with bulbs of the clinical type thrust into joints within a few centimeters of the one being measured, but which had equivalent exposure. These and previously published measurements establish the following points:

Growth in *Opuntia* may begin at 9° C. and extend to 58° C.

Growth of young joints of *Opuntia*, the temperature of which rose to 62° C. (144° F.) in an air temperature of 63° C. (146°F.), stopped and some shrinkage ensued, but growth or enlargement was resumed when their temperature fell to 50° C.

A new high record of 58° C. (137° F.) for growth in *Opuntia* and for the higher plants has been established by these experiments.

The maximum rate of growth of *Opuntia* occurs between 37° C. and about 47° to 49° C., under which conditions a biocolloid consisting of 9 parts agar and 1 part protein undergoes maximum swelling in water.

The cell colloids of *Opuntia* include a large proportion of pentosans or mucilages, the colloidal condition of which is in general less affected by the temperatures used than albuminous substances. It is to be noted, however, that bacterial cells, which are highly albuminous, may withstand high temperatures such as those of boiling water.

The young joints which were subjected to these temperatures were about 15 to 20 mm. in width and 25 mm. in length, and after being held at or near the record temperatures for an hour or more, which was repeated in one case, they carried forward normal development, reaching maturity at a normal average of 100 mm. in width and 130 mm. in length.

It is to be noted that data from observations in which temperatures were taken from the air or from water in which the roots or aerial parts of plants were immersed have but little value in any estimation of the working temperature of active protoplasm by reason of the abnormal hydration and transpiration conditions introduced. These conditions, as well as the proportions and state of the main colloidal components, must determine the temperature effects.

The salts of the common bases are known to increase the coagulating effects of temperature on protoplasm according to their speed in permeating the plasma. It would appear that of the common bases or kations, potassium would exert the least effect, sodium and calcium more, and magnesium most, while the nitrates have a lesser effect than the chlorides, with the greatest effects in the citrates and sulphates. (See Kahho, Hugo: Ueber die Hitzekoagulation des Protoplasmas durch Neutralsalze. Biochem. Zeitschrift, 117, p. 87. 1921.) Capacity for endurance of high temperatures would suggest the presence of low proportions of salts, giving decreased coagulation effects.

Physical and Chemical Factors in the Growth of Asparagus, by Earl B. Working.

The great mass of chemical information on plant materials concerns seeds, tubers, and other storage tissues, and is therefore unavailable for a study of the chemical factors of active growth. As it is the young shoots of asparagus which are of economic importance, perhaps more is known of their chemistry than of the chemistry of any other plant in comparable rapid-growing regions.

As a preliminary survey, the hydration capacities of the asparagus in a large variety of solutions were tested by means of the auxograph, and growth and temperature records were made both in the light and in darkness. Both seedlings and young shoots from established roots were tested in each type of experiment.

In the physical field, both temperature effects and light effects offer promising opportunities for further investigation. From the chemical side, the action of sodium and that of balanced solutions, such as sodium and calcium, seem to offer the most attractive field for detailed study. There has long been a common belief that the application of common salt to asparagus is advantageous. This has been both affirmed and questioned by investigators.

The commercial asparagus fields of the San Joaquin Valley and of the Sacramento Islands were given considerable study. The islands of the Sacramento River comprise probably the largest fields of asparagus in the world and are an especially interesting study, because in the lower end of the asparagus region the waters become decidedly brackish when the river is low.

Root-Growth in Relation to a Deficiency of Oxygen or an Excess of Carbon Dioxid in the Soil, by W. A. Cannon.

The leading results of studies on the relation of root-growth to the aeration conditions of the soil, and which have been referred to from time to time in the Year Book, may be formally presented as follows:

1. The reaction of roots to a deficiency of oxygen or to an excess of carbon dioxid in the soil was investigated in thirty species of plants and observed to a certain extent in several more. The habitats from which the species were derived or the cultural conditions under which they are growing are extremely varied, ranging, in the case of the former, from swamps on the one hand to the arid mesa of southern Arizona on the other.

2. All of the species studied appear able to maintain root-growth in an atmosphere containing 2 per cent oxygen, provided the amount of carbon dioxid present is not as great as 30 to 50 per cent.

3. Several species, including *Baccharis vimines*, *Citrus sinensis*, *Juncus effusus* var. *brunneus*, *Potentilla anserina*, and others, are able to continue root-growth, although at a relatively slow rate, for more or less extended periods in a soil-atmosphere containing 5 per cent oxygen, the remainder nitrogen, and in relatively large amounts of carbon dioxid, as in 50 per cent, provided the oxygen partial pressure is normal or not far below.

4. When oxygen is entirely removed from the soil-atmosphere, no root-growth in any species takes place.

5. The species mentioned in paragraph 3 occur naturally in substrata saturated all or most of the time. It does not follow, however, that all species growing in water have similar oxygen relations. For example, *Nasturtium officinale* appears to require as high a percentage of oxygen for root-growth as many plants from well-aerated soils. A good condition of aeration in the case of *Nasturtium* is possibly provided by active water movements.

6. The studied species of *Avena*, *Hordeum*, *Oryza*, *Phalaris*, *Triticum*, and *Zea* can maintain root-growth, although at a slow rate, in a soil-atmosphere containing as little as 0.5 per cent oxygen, remainder nitrogen. These species, however, appear not to hold equal relations to a deficiency of oxygen. Thus, *Zea* is dependent on a fairly good oxygen-supply.

7. Species from well-aerated soils may have unlike oxygen relations. Thus, in the sandy soil at Carmel may be found *Mesembryanthemum* and *Erigonum*, which are relatively insensible to oxygen deprivation, and also *Stachys*, which, on the other hand, requires a good oxygen-supply. The soil of this habitat is never puddled. *Opuntia*, *Fouquieria*, and *Covillea*, which are relatively intolerant of poor conditions of soil-aeration, occur on the bajada slopes near Tucson. The bajada soil is coarse and is well aerated most of the year, but it is puddled during the short rainy seasons, at which time gaseous exchange is slow. On the flood-plain of the Santa Cruz River at Tucson, *Prosopis velutina* occurs under somewhat similar conditions and *Medicago sativa* is cultivated. The soil of the flood-plain is of fine texture and puddles easily. Indeed, in former times the flood-waters spread as a

shallow sheet, covering this plain. In the case of the cultivated species, flooding takes place at fairly frequent intervals through irrigation. Under both conditions, therefore, owing mainly to slow percolation, poor aeration of the soil may occur. Both of the species referred to are relatively but not highly tolerant of poor conditions of soil-aeration, and root-growth may or may not continue in a soil-atmosphere containing 0.5 per cent oxygen, remainder nitrogen. It is to be noted that so far as concerns *Prosopis* the soil may be well aerated during the long dry seasons.

8. When the amount of oxygen in the soil is diminished to the point where root-growth may or may not take place, the growth of the roots may continue, provided the gaseous mixture is caused to stream slowly through the soil. It is the rate of supply and not the partial pressure of the gas that is of moment. In *Stachys*, for example, root-growth ceases in a static soil-air containing 0.5 per cent oxygen, while growth will continue if the same gaseous mixture is slowly streaming. A similar condition was observed in several other species.

9. A deficiency of oxygen may be said, in general, to exist when the oxygen comprises 10 per cent or less of the soil-air, with the remainder nitrogen; and an excess of carbon dioxid can be said to be 50 per cent, more or less, of the soil-atmosphere when there is normal oxygen partial pressure, and probably less than 50 per cent when the amount of oxygen is low.

10. There is in some species, if not in all, a direct relation between tolerance to a deficient oxygen-supply and the temperature of the soil. In *Prosopis*, for example, it was observed that when the temperature of the soil was about 10° C. below the optimum, growth stopped upon the administration of a gaseous mixture poor in oxygen, but it was renewed with the same soil-air when the temperature was raised to optimum.

11. Vigorous seedlings are most resistant to deficiency of oxygen.

12. The size of the cotyledons in *Prosopis* apparently holds a direct relation to the amount of oxygen in the soil-air. The cotyledons are relatively small when the oxygen partial pressure is low.

13. The hypocotyls of *Prosopis* appear to be insensible to a deprivation of oxygen.

14. In certain species, for instance *Opuntia*, *Pisum*, and *Zea*, there may be a differential response to a condition of poor soil-aeration by the roots in one and the same plant. Thus, in the case of the two species first named the main roots are less tolerant to poor aeration than are the laterals, roots of smaller size or of lower rank, while the opposite appears to be the case in *Opuntia*. So far as *Opuntia* is concerned, it is possible that the reaction is in a direction looking toward a superficial placing of the lateral roots, which is a characteristic of the mature plant.

15. In *Zea mays* the geotropic response of the roots appears to be much weaker in a soil-atmosphere containing 2 per cent oxygen than in normal air.

16. The first observable morphological effect of poor aeration in *Pisum sativum* is a shrinking of the meristematic tissue of the root-tip. If this alteration proceeds beyond a certain stage, recovery upon the admission of air does not take place; if, however, the reaction has not progressed far, recovery is possible. In the last event the effects of the reaction to a condition of poor aeration may persist for a period as a constriction of the growing root.

The Action of Vitamins, Amino-Compounds, and Salts on Hydration,
by D. T. MacDougal.

The assertion was made in an earlier report that the salts of the common metals which enter into nutritive solutions, as potassium, magnesium, sodium, and calcium, might find their chief importance in restricting, limiting, or defining hydration. Such an action is exerted by these bases in the form of hydroxides when tested at 0.001N. MacDougal and Spoehr found later that the hydroxides of the strong metallic bases limit the hydration of agar according to their position in the electromotive series, the least swelling taking place under the action of the strongest base at concentrations of 0.01N, with the apparent exception of rubidium. Beginning with the strongest, the series runs K, (Rb), Na, Li. The various effects of barium, calcium, and strontium are not so clearly determined, and the quantitative relations of these metals are not known definitely. Hydration values of agar at 0.01N were $Sr(OH)_2=815$, $Ca(OH)_2=860$, $Ba(OH)_2=900$. These concentrations are far beyond the actual range of conditions in the cell, however, and when reduced concentrations were used it was seen that the hydration of agar in calcium hydroxide exceeds that in water at 0.0001N of the hydroxide, and this effect is also produced at 0.00001N. There was increase of hydration beyond that of water by dilute solutions of hydroxides of calcium, potassium, rubidium, sodium, and lithium, and excess values for aniline and ammonium hydroxides were obtained. It was also seen that the strongest of the bases, potassium, in the form of hydroxide would increase the swelling of agar-albumin mixtures to a point beyond that taking place in water alone.

The next logical step was to test the effects of salts of the common metals on swelling of the biocolloidal components. Here again the interesting fact was found that as chlorides sodium and potassium at 0.001M caused greater hydration of agar than water, the swelling being greater in the potassium. At 0.0001M, sodium, potassium, magnesium, and calcium chlorides caused greater swelling than in water, the maximum swelling being in sodium, the next in potassium, and the least in calcium.

When chlorides of sodium and potassium were tested, it was found that pentosan-albumin mixtures simulating protoplasm showed increased hydration in the potassium chloride only as indicated in the tables.

Up to this point colloids including only two of the supposed main elements in protoplasm have been used. An agar-gelatine mixture was now made, to which was added a thousandth part of a soap which is probably nearly all sodium stearate. The results of the hydration swellings are given below:

Hydration of plates of agar 3, gelatine 2, Ivory soap 0.005 g. at 15° C. Swellings given in thickness and volume.

	0.01M.		0.0002M.		0.0001M.	
	Th.	Vol.	Th.	Vol.	Th.	Vol.
NaCl	890	9,020	....	....	2,330	2,600
Balanced solution (Na 50 : Ca 1)	810	842	....	....	2,460	2,660
$CaCl_2$	850	920	1,200	1,374	2,600	2,940
KCl	970	1,050	....	....	2,750	2,050
HCl	1,280	1,460	1,130	1,270	1,200	1,250
Water	....	....	....	....	1,500	1,700

This biocolloid, representing more nearly the colloidal constitution of living matter, was seen to have higher hydration capacity in all salt solutions and to have such capacity lessened in even the very dilute acid. A similar preparation, in which the soap was pure potassium oleate, gave results less marked as to the action of the salts, but the increase in the balanced solution was proportionately much greater and the retarding effect in acids much greater. Ample justification exists, therefore, for a correction of the earlier statement as to the effect of salts of the common metals on biocolloids, which have been found to offer many profitable analogies to living material. The correction implies that we may confidently look to these salts as accelerators of hydration and growth or as increasing the water-deficit of living matter.

I have previously pointed out, in many papers, that the commoner amino-acids (glycocoll, alanine, phenylalanine, asparagine, and histidine) which have been proved to promote growth also accelerate hydration in biocolloids.

As an additional step in this work, the effect of the water-soluble B-yeast vitamin on biocolloids and living and dead cell-masses was measured. Solutions of this material at 0.1 per cent, having an acidity of PH=5.25 as determined by the colorimeter method, were used, and measurements were taken by the auxograph. The vitamin was seen to increase the hydration swelling, water-capacity, or water-deficit of agar, agar-soap, agar-gelatine, agar-gelatine salts, and gelatine, but to lessen hydration in some biocolloids containing soaps which would be sensitive to the free hydrogen ions of the vitamin solution. Parallel action in living and dead cells is implied, although it is to be noted that such cells may already include a certain amount of their characteristic vitamins and that the added vitamin could exert no additional effect except that of reducing hydration capacity. The theory as to the constitution of living matter by which plant protoplasm is taken to be a pentosan-albumin-soap colloidal mixture has been found adequate in such experiments.

The metals which form the bases of nutrient salts of plants, as chlorides and nitrates, are found to increase the hydration capacity or the water-deficit of the principal components of biocolloids and of biocolloids of certain composition.

Biocolloids containing soaps show a high degree of sensitiveness to hydrogen ions or acidity. Such biocolloids show marked action in balanced solutions of sodium and calcium, as shown by data too detailed to be given in this paper.

Water-soluble B-yeast vitamin in a solution slightly acid increases the swelling, hydration, or water-deficit in some living and dead plant cell-masses and lessens it in others. Similar diverse action on biocolloids was found.

All of the substances tested which are known to facilitate growth in plants are found to increase hydration capacity or water-deficit in some of the test objects. The list includes chlorides and nitrates of sodium, potassium, magnesium, and calcium in various concentrations between 0.001N and 0.0001N, glycocoll, alanine, phenylalanine, histidine, and water-soluble B-yeast vitamin. Hydroxides of sodium, potassium, lithium, rubidium, calcium, ammonium, and aniline also increase hydration values in some components of living matter.

The Action of Bases and Salts on Biocolloids and Cell-Masses, by D. T. MacDougal.

The suggestion was made in an earlier paper that the common metals which enter into nutrient solutions might find their chief importance in restricting, limiting, or defining hydration of the cell-colloids. MacDougal and Spoehr carried out a series of tests upon this matter and found that the strong metallic bases when used at concentrations of 0.01N do limit or restrict the hydration of agar according to their place in the electromotive series, the least swelling taking place under the action of the strongest base, with rubidium unplaced. Beginning with the strongest, the series runs K, (Rb), Na, Li, and if calcium were added to the series the swelling under its action was less than that in potassium. When the concentrations were reduced, however, to

0.001N it was found that hydroxides of all of the metals increased the hydration capacity of agar. This was of importance, as a review of all available data seems to show that the range of the H^+-OH^- balance in the plant-cell lies between the values expressed by PH_3 and PH_{11}, or between about 0.01M aspartic, succinic, or propionic acid and under 0.001N KOH.

The reversal of effects at great attenuations in the hydroxides led to the extension of auxographic measurements upon the effects of low concentrations of the salts which are of such interest and importance in cultures, and the action of chlorides, nitrates, and sulphates of potassium, calcium, sodium, and magnesium upon agar, gelatine, and mixtures was made at Carmel in the summer of 1920. The action of these reagents upon living and dead cell-masses was also tested late in the summer of the same year. The principal results of the entire series of experiments may be summarized as follows:

The strong metallic bases, which were found to lessen the swelling of agar to a degree corresponding to their relative positions in the electromotive series when used as hydroxides, give the same relative action when used as chlorides. The series runs Ca, K, Na, the greatest retardation being affected by the calcium and the least by sodium when used at concentrations of 0.01M.

Reversed effects by which hydration of agar is increased are shown by the hydroxides at 0.001N, as described in a previous contribution, but no well-defined differences among the bases used could be made out. Similar reversed effects were exhibited by the chlorides of calcium, magnesium, potassium, and sodium at 0.0001M and by potassium and sodium in concentrations as great as 0.001M.

Purified agar used in the experiments has a PH value of 6.5, also swells more in HCl at a PH value of 4.2 than in water, a statement be applied in correction of various conclusions in previous papers.

Purified agar shows exaggerated swellings in a series of acid, salt, and hydroxide solutions in which the hydrogen-ion concentration ranges from PH 4.2 to 11.

Purified agar also shows exaggerated swellings in sodium and potassium nitrates at 0.0001M, but not in the sulphates.

Of the chlorides of calcium and potassium and hydrochloric acid at concentrations from 0.01M to 0.0001M only KCl at 0.001M and 0.0001M increase the swelling of an agar-gelatine mixture. In a similar series only KCl at 0.0001M increases swelling in a gelatine-agar mixture.

Agar plates with included chlorides at concentrations increasing swelling, when applied as hydrating solutions, showed exaggerated swelling in HCl, NaCl, KCl at 0.0001M, but a lessened swelling in $CaCl_2$ and $MgCl_2$ at this concentration.

Gelatine plates, with incorporated salts as above, showed swelling in HCl increasing with the concentration beginning with the 0.001M solution, in reverse of the action of the $CaCl_2$ solution, which was greatest but still less than in water until at 0.0001M. Swelling in KCl did not exceed that in water until a concentration of 0.01M was reached.

The maximum swelling of a gelatine (3 parts)-agar (2 parts) plate is greatest in HCl 0.01N, KCl 0.001M, and $CaCl_2$ at 0.0001M.

Different ecological types of roots of maize show different hydration reactions to the solutions used in hydration tests of colloids, as noted in the foregoing paragraphs.

Roots of strawberry show differing hydration reactions when grown in saline soils and in sand.

Roots of orange seedlings show lessened hydration in acid solutions, and their hydration was lessened in all solutions except balanced solutions of sea-water and of sodium and calcium chloride.

Swellings of sections of joints of *Opuntia* were greatest in KOH at 0.01N, HCl at 0.001N, and KCl at 0.0001M, all producing effects in excess of the swelling in water.

The changes in volume of living cell-masses in hydrating solutions include osmotic-plasmolytic effects in the alterations of the volume of the included cells. The hydration of dead cell-masses includes possible osmotic action of cell-walls.

The hydration reactions described in this paper may include coagulation effects when the higher concentrations were applied to the biocolloids, similar to those of the plasmatic colloids. Actual effects of balanced solutions are clearly defined in the hydration of agar, and some suggestions of similar action in the biocolloids arise from the measurements of swelling of the biocolloids described.

Effects of Age and of the Inclusion of Salts on the Heterotropic Action of Colloidal Bodies of Cytological Interest, by D. T. MacDougal.

Auxographic measurements of the swelling of sections of dried plates of agar and of gelatine previously described show that the relative enlargement of a colloidal body in its different axes will be determined largely by the unequal stresses which may be set up, as, for example, when liquid agar or gelatine is poured on glass and dried without shrinking in area. It was pointed out that sections from such plates of agar increased only 3 or 4 per cent in length while swelling 3,000 or even 4,000 per cent in thickness, and that sections of gelatine increased 8 to 40 per cent in length while swelling from 500 to 2,000 per cent under the auxograph.

Tests of sections of plates of pure agar freshly made and a year old have been made. Plates which swelled 2,000 per cent in water when freshly made August 1, 1919, increased but 1,600 per cent July 1, 1920. Plates swelling 3,200 per cent when young, increased but 2,000 per cent when nine months old. This total decrease was accompanied by lessened swelling in thickness and increased swelling parallel to the broad surfaces of the plates. The relative increase in length and width of sections of old plates was double that in the same plates when newly made and swelled in water. Similar increases occurred when old plates were hydrated in chlorides of K, Na, Mg, and Ca at 0.0001M.

The effects of age on gelatine plates are not so marked, but the areal swelling increases with age. The differential effects of the various solutions on such areal or linear increases were very marked and noticeable. Thus, strips 30 to 50 mm. in length cut from a single plate when placed in the solutions gave increases in thickness and length as below:

	0.01M.		0.001M.		0.0001M.	
	Th.	L.	Th.	L.	Th.	L.
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
KCl........	1090	38	800	33	640	35
CaCl.......	600	6	1350	8	830	10
HCl........	1620	70	1600	20	925	8
Water......	....	....	....	....	780	8

The areal increase in the potassium solution varied but little in the different concentrations, being much greater than in the calcium, which was near that in water. The greatest disproportion, however, between increase in thickness and in length was in the acid.

Agar was made into plates with an inclusion of minute proportions of chlorides of calcium, potassium, and magnesium which would represent possibilities in the plant-cell. When such salted plates were hydrated in solutions of KCl, NaCl, and HCl at 0.0001M, the swelling in length amounted to 12 to 14 per cent, as compared with increases of 3 to 4 per cent which might be shown by pure agar.

Equally interesting results were obtained with salted gelatine. Among the more important effects it is to be seen that the increase in length of therotropic plates is lessened by the incorporation of salts when swelled in KCl. The presence of incorporated salts accelerates increases in length in $CaCl_2$ in an uncertain manner, but exercises such an effect rising with the concentration in acid. The presence of incorporated salts lessens the increase in length in KCl, does not modify it greatly in HCl, but exaggerates the increase in $CaCl_2$ at 0.01M.

The significance of the above data lies in the fact that living matter and the structures in the cell, to which so much importance in heredity and physiology is attributed, are bodies in a similar colloidal state.

Their changes in form, increase or decrease, division, etc., are inevitably affected by the factors described. No conception of matter free from fundamental physical laws can be entertained or successfully maintained.

Biocolloids as Membranes; a New Colloidal Cell, by D. T. MacDougal.

My earlier investigations upon the fundamental mechanism of enlargement of cells and the growth of organs were concerned chiefly with the increases which the solid mass of the protoplasm undergoes by swelling as influenced by the nutrient salts, acids, hydroxides, amino-compounds, and vitamins. The information gained, which has been published in numerous papers, may be taken to apply chiefly to cells in the earliest stage of their development.

The cell or protoplast of the plant is at first a microscopic mass of a gel in which are included denser bodies or organs, such as the nucleus and plastids. As the protoplast enlarges by swelling or hydration and by the addition of more material, cavities or spaces are formed within it by the process known to the physicist as syneresis, and these cavities persist as vacuoles. The water which fills these clear spaces contains solutions of acids, salts, sugars, and amino-compounds of the cell in varying concentrations. While these internal cavities are developing, a dense and tough outer wall of "cellulose" has been formed around the protoplasm, and these two changes convert the cell into an osmotic machine which pulls liquids into the interior of the cell or loses solutions out through its walls in accordance with the osmotic activity of the various substances concerned and the permeability of the membranes. The way in which this passage of solutions occurs is largely determined by the character of the firm outer wall of the cell, by the plasmatic layer which lies against it, and by the special membrane or layer which is formed at the surfaces of the wall and protoplasm in contact. These may show widely varying qualities as to permeability.

In the earlier experiments it was found that a mixture of agar, gelatine, and soaps and lipins in hydration and swelling afforded many profitable parallels with the behavior of living and dead cell-masses, and as living matter may be safely taken to be made up chiefly of carbohydrates, albuminous substances, and soaps or combinations of the fatty acids with calcium, potassium, or sodium, the experiments were extended to include a study of the influence of a mixture of these colloids on osmosis under conditions similar to those prevailing in the plant cell.

In carrying out this purpose a new form of artificial cell or osmotic apparatus was devised, which has yielded some results of value in the consideration of the action of the living cell. The living cell has a firm outer wall, which is permeable to the solutions of the salts of the common metals found in the soil and which are important in nutrition, but it may not permit more complex substances to pass readily. These features are represented in the new colloidal cell by the cylindrical clay cup used in the Livingston atmometer, which has a length of about 12 cm. and an internal diameter of 2 cm., is closed at one end, and has a capacity of from 35 to 40 c. c. The walls of the cup have a thickness of about 2 mm., and when it is closed with a stopper with suitable fixtures it may be used directly in osmotic tests of great interest. Tests show that the solutions of the soil salts pass through the clay walls almost as readily as water, while sugar and other organic compounds are retarded, so that when such substances are used to fill the cell a positive osmotic pressure may be set up.

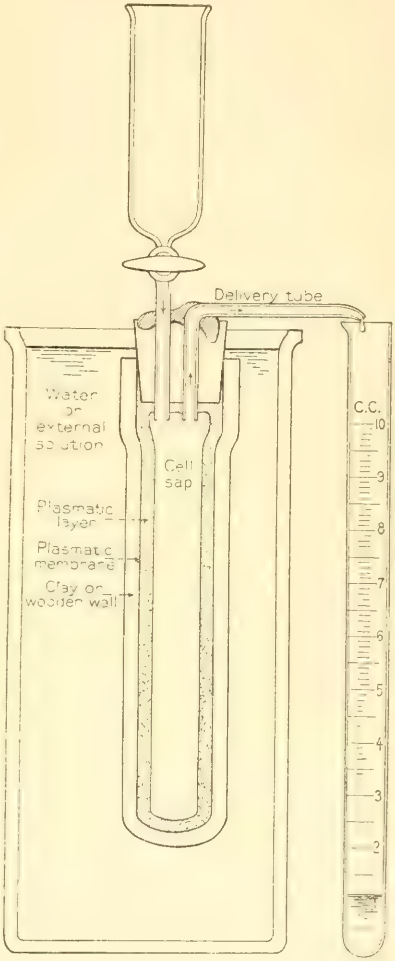
The plasmatic or living layer of the cell is represented in this cell by a lining layer of a gel consisting of two parts of agar, one of gelatine, and one-thousandth part of calcium or potassium oleate and an equivalent amount of some lipin. A sufficient quantity of such a mixture is poured into the cup while warm, so that when the cup is closed by an osmometer head and the cup slowly rotated in the hand the colloids set as a gel 3 mm. in diameter over the entire interior surface.

The osmometer head is fitted with a separatory funnel, by which solutions representing the cell contents may be introduced, while a second delivery or exit tube conducts out any excess which may accrue from the positive action of the cell, and this is collected in a graduated test-tube. When it is stated that the lining colloidal layer forms a special layer where it comes in contact with the cell-wall, simulating the plasmatic membrane of the living cell, the principal features of the colloidal cell have been enumerated.

Chief interest in the cell in the present connection centers in the action by which it absorbs solutions from the soil or water in which the plant may be growing. The most important experiments with the new cell, therefore, were those in which it was given a sap or content of varying character and placed in solutions of known composition to test its action. The first illustration of the fact that the new cell is not a simple osmometer consists in the difference in results when it is filled with a sodium solution as contrasted with the effect of a potassium solution of equimolecular concentration. The cell with the potassium (chloride) sap and potassium soap in the plasma absorbs about twice as much water as the sodium cell and ten times as much as a calcium or magnesium cell with a sap of identical molecular concentration. Furthermore, some of the effects of balanced solutions of sodium and calcium are to be seen in the action of the new cell.

Among the more interesting features of the action of this device are the operations which parallel those of plasmolysis and of adaptive adjustments of the living cell. Furthermore, as may be seen by the following paragraph, much important information may be gained as to the time relation in osmosis. Osmosis has been chiefly studied from a thermodynamic viewpoint, consideration being given to equilibria rather than to rate of action, although the speed of penetration of membranes and the duration of the processes have always been uppermost in the mind of the physiologist. Some of the possibilities in this field are suggested by the action of a colloidal cell filled with water and immersed in water.

In the beginning the action must consist partly of hydration or swelling of the plasmatic layer by water taken up from the cell-contents and drawn in through the clay wall. At the same time some of the colloidal electrolytes of the plasma are passing into solution in the cell-sap, with a resultant osmotic action of the dissociated material. The endosmosis taking place increases the contents, the surplus passing out through the delivery tube at a rate which increases for 4 to 7 days, after which a gradual lessening of the rate takes place which, however, may allow as much action on the fortieth day as on the first, which would be about one-third of the maximum shown on the fifth or sixth day. The plotting of the varying rates results in a graph of the type of the "biological curve," by which the activities of a cell or organism may be expressed during its lifetime. The action of the cell depends chiefly on the fact that the material of the gel or "plasma" of the cell, which has an approximate dry weight of 1 gram, passes slowly into solution, and, being composed of colloidal electrolytes, osmotic activity ensues, which causes water to enter the cell, with the expulsion of an equivalent amount. The loss of water in this manner implies a loss of dissolved material and is ghly suggestive of certain forms of secretion in plant organs.



Section of an artificial cell arranged to show continuing osmotic action of colloidal layers as in a living cell. Such cells filled with water showed positive osmose for periods of two or three months at a rate varying in a "biological curve."

The differential action of potassium, sodium, magnesium, calcium, etc., may be taken to be due to the specific action which the salts of these substances exert on the solution of the colloidal material and on colloidal aggregation.

Some features of plasmolysis and of adaptive reactions of living cells are suggested by the reactions of the colloidal cells filled with water when immersed in a series of salt solutions ranging from 0.001M to 0.008M. The cells in the weaker solutions begin to operate positively and to deliver liquid through the exit tube soon after setting up. Those in the stronger solutions show exosmosis or loss of liquid through the outer wall for the first day, when a reversal takes place and absorption or intake of liquid results from solutions as concentrated as that indicated by the higher figure given above. A colloidal cell, which at first shows negative action, then reverses its action and absorbs from the immersion fluid at a certain concentration, may be stepped up to a higher concentration in which it would show loss only if placed in this liquid initially.

PHOTOSYNTHESIS, RESPIRATION, AND NUTRITION.

Carbohydrate-Amino-Acid Relation in the Respiration of Leaves, by H. A. Spoehr and J. M. McGee.

In order to pursue the investigations on the carbohydrate economy and respiration of chlorophyllous leaves with greater accuracy and more economy of time, the experimental procedure was modified so as to employ largely electrical methods. The carbon dioxid emitted by the plants was absorbed in solutions of barium hydroxide, and titrations were replaced by the determinations of the electrical conductivity. It was necessary to determine the electrical constants of the barium-hydroxide solutions which give the maximum change of resistance per unit change of concentration consistent with the use of such solutions sufficiently concentrated to completely absorb the carbon dioxid in the air-stream. The experimental conditions were so adjusted that concentrations of 0.08 to 0.17 normal barium hydroxide were used. By the employment of suitable devices for the sedimentation of the barium carbonate and special conductivity cells very accurate and rapid determinations of the respiration rates were accomplished.

The stimulating effect of the amino-acids on the respiratory activity and carbohydrate consumption of leaves has been repeatedly substantiated. Glycocoll, alanine, and asparagin vary in this effect, apparently according to the ease of penetrability. When glucose is given the leaves as the carbohydrate food material this stimulating effect is most marked. With saccharose the effect is also noticeable. With mannose no such reaction could be observed. The experiments with fructose indicate that amino-acids have actually a depressing action on the rate of respiration. No satisfactory explanation of these results has thus far been obtained. Experiments conducted to reveal a possible isomerizing action of the amino-acids on these various sugars *in vitro* as well as in the leaf yielded only negative results. Efforts are now being directed to determine the enzymatic relations in the leaves and how these are influenced by the various nutritive conditions. Herein special attention is given to the catalase and peroxidase activities. These are of importance not only to the respiration of the leaf but also to the photosynthetic activity, and it now seems highly probable that herein lies the link which so intimately binds these two processes.

The analytical determination of amino-acids in plants ranging from germinating seeds to mature plants has been continued in connection with their respiratory activity and carbohydrate content. It has become evident that in these relationships the chlorophyllous leaves are quite differentiated from other parts of the plant. These investigations are now being extended to include a study of the circumstances which make for the synthesis of proteins and their breakdown into simpler compounds.

The Internal Factor in Photosynthesis, by H. A. Spoehr.

The only reliable methods which have thus far been developed for the study of photosynthesis in land plants are those based upon gas analysis. In attempting to improve further the apparatus used in these studies, various other methods were tried out which made use of various different principles other than the differential determination of the carbon dioxid in the air-stream passing over the illuminated leaf. None of these proved as accurate nor as convenient as the latter. Methods were therefore devised which made use of the electrolytic determination of carbon dioxid by means of absorption in solutions of barium hydroxide, as had been done in the investigations on respiration. Suitable absorption tubes and sedimentation vessels of glass were constructed, which permit of complete absorption of the carbon dioxid. By means of a special electrolytic cell of high resistance the electrical conductivity of the barium-hydroxide solutions can be measured with both great accuracy and rapidity.

Since these investigations were started a mass of evidence has accumulated which supports the dictum that an essential rôle in the photosynthetic process must be ascribed to the protoplasmic activity of the colorless components of the chloroplasts. The existence of an essential internal factor can be concluded not only from the failure of all attempts which have been made to reproduce photosynthesis outside of the living cell but also from direct experiments with living leaves. That this factor is not to be sought in the chlorophyll components or in such physical conditions as the degree of dispersion of the chlorophyll pigments follows from the great and irregular disproportion which has been found to exist between the chlorophyll-content and photosynthetic activity. The experiments on this subject have shown that the relation between photosynthesis and respiration is an intimate one, and that this relationship holds both on an ascending and on a descending rate of either process. The experiments are now being directed to determine whether this relation is actually on an energetic basis or whether it is of a chemical nature, i. e., dependent upon certain components of the protoplasm, which vary in amount or with the metabolic activity. Whether the former state exists can be determined by a study of the temperature coefficient of photosynthesis under varying conditions of carbohydrate-content and respiratory activity. The possible chemical dependency may perhaps be determined by a study of the enzymatic relations, more especially of those enzymes which are active in the respiratory activity, catalase, and peroxidase, and which, from the data thus far obtained, also function as a step in the photosynthetic process. Both of these lines of investigation are being pursued, for which the constant-temperature rooms of the new laboratory at Carmel offer excellent facilities.

Reduction of Pentose Sugars, by H. A. Spoehr and J. W. E. Glattfeld.

For the continuation of these investigations (Carnegie Inst. Wash. Year Book 1920, pp. 64-66), Dr. J. W. E. Glattfeld, of the University of Chicago, again spent January, February, and March as a Research Associate at the Desert Laboratory. In order to simplify the usual cumbersome and time-consuming procedure of carrying out reducing reactions with large quantities of sodium amalgam, a rotary agitator was devised. This contrivance, driven at a very high speed, accomplished the mixing of several kilograms of sodium amalgam with the aqueous sugar-solution to a thick colloidal mass. With the agitator and by means of suitable cooling and the control of acidity of the mixture, the time of the reaction was diminished to half of that ordinarily required, and the amount of amalgam necessary to reduce a given quantity of sugar was also diminished. By this means several hundred grams of pure xylit were obtained. All attempts at getting the xylit to crystallize have failed, however, nor has it been possible to obtain a quantitative reduction of the sugar; there is always formed a small quantity of sugar gum. This does not reduce Fehling's solution, but on treating with hydrochloric acid gives a decided reduction. The composition of this gum has not yet been established. The xylit was dehydrated by means of anhydrous formic acid. This mixture was distilled, and besides gaseous products, water, and formic acid, it yielded a volatile oil which on account of its ease of polymerization it has not been possible to identify.

The New Chemical Laboratory at Carmel, by H. A. Spoehr.

In March of 1921 work was begun on the construction of the new laboratory at Carmel. The apparatus and equipment of the chemical laboratory at Tucson was packed and shipped to Carmel and in August the new laboratory was ready for occupancy. This building is a single-story structure, 42 by 32 feet, built of brick, with partitions of the same material and a concrete basement. The latter is entirely below ground and contains two constant-temperature rooms to the construction of which special attention was devoted in order to secure perfect insulation. Floors, inside partitions, and doors are insulated by means of hair-matting, a dead-air space, and mineral wool. The upper floor contains a chemical laboratory 23 by 18 feet, a room for physiological work, with water thermostats, etc., 20 by 15 feet, an office 16 by 13 feet, and a machine and store room 21 by 11 feet. A glass-inclosed porch 12 by 12 feet provides excellent outside working space. The entire building is equipped with water, gas, vacuum, compressed air, and numerous receptacles for 110 and 220 volt alternating-current electricity. A 3.5 k. w. motor generator set provides direct current. The gas is produced by a de Laitte gas-machine of 320 cubic feet per hour capacity, placed in a separate small building.

Anaerobic Experiments with Argon, by W. A. Cannon and E. E. Free.

In the annual reports of this Department for 1919 and 1920 there were described experiments in which helium was used, instead of the more usual nitrogen, as the diluting gas in experiments with the growth of roots and other plant parts under partial anaerobic conditions. It was discovered that nitrogen and helium did not behave exactly alike, the amount of oxygen necessary for growth being somewhat greater when the diluting gas was nitrogen than when this was helium. It was suggested that the explanation of these effects might lie in the greater rapidity of diffusion of oxygen through helium than through nitrogen.

In order to test this diffusional hypothesis, experiments have now been made in which argon was used as the diluting gas; the results are the same as those with nitrogen. The same concentration of oxygen is necessary in each case for a given plant activity. It is believed that this result furnishes strong confirmation of the diffusional hypothesis, the rate of diffusion of oxygen through argon being practically the same as through nitrogen, while the argon is as free from suspicion of direct chemical activity as is helium.

Tests in which hydrogen was used as the diluting gas indicate that this gas behaves almost the same as does helium. This fact is also confirmatory of the diffusional hypothesis, but the tests with hydrogen are not sufficiently numerous to constitute important evidence.

Some Aspects of Metabolism in the Fungi, by B. M. Duggar.

Much valuable knowledge has been added to the literature bearing upon the metabolism of the fungi. Nevertheless, the nutrition of these organisms still offers a variety of problems which may throw light upon the phenomena of metabolism in general, and may serve, further, to indicate the causes of diversity or to relate these to conditions of growth.

For the most part the organisms which have been studied in the past are the familiar saprophytic species of the laboratory, such as *Penicillium*, *Aspergillus*, and *Rhizopus*, together with forms of technical and industrial interest, including the yeasts. In the study which the writer has undertaken it is proposed ultimately to include forms which are diverse both in taxonomic relationship and in habitat or in effects. So far the organisms employed have been chiefly those inducing disease in plants or decay in timber, and they include 19 species belonging to the following genera: *Aspergillus*, *Botrytis*, *Fusarium*, *Giberella*, *Glomerella*, *Helminthosporium*, *Penicillium*, *Polyporus*, *Sclerotinia*, and *Sphæropsis*.

Following some experiments carried out during the preceding year at the Missouri Botanical Garden, it seemed desirable at the outset to simplify the media employed as far as possible, using relatively few sources of carbon and nitrogen. As mineral constituents of the nutrient solutions, there have been employed concentrations of magnesium sulphate and potassium dihydrogen phosphate to give in the cultures 0.02M and 0.05M, respectively. Ferric chloride has been used to give a concentration of only 0.00004. As a source of carbon, 0.25M glucose or 11 per cent peptone has been employed, and either potassium nitrate, ammonium nitrate, or peptone as a source of nitrogen. The nitrates were used in a concentration of 0.2M, and the peptone was made of such strength as to contain the same amount of nitrogen in the concentration of potassium nitrate used. The cultures were arranged in Erlenmeyer flasks, and in the series here reported they were grown at 58° F. and at 61° F. The amount of growth was measured by the dry weight of the fungus mat.

It is recognized, of course, that any form of carbon as a source of energy must ultimately yield carbon dioxid, but it does not follow that the course of metabolism, especially with relation to the by-products produced, would be the same in all the organisms, nor would it be necessarily the same under the influence of different sources of nitrogen. In any case, it was desirable to determine, first of all, the relation of the source of nitrogen to the growth of the various organisms employed. The results so far achieved are referred to in this section of the report. In the following section the changes in H-ion concentration will be briefly considered.

In every instance except one (a species of *Fusarium*) the maximum yield was in the combination of glucose and peptone as sources of carbon and nitrogen, respectively. The organism which gave the highest growth-quantity in this medium was *Botrytis cinerea.* On the other hand, peptone as a source of both carbon and nitrogen gave the lowest yield in every instance except one, which fact is significant, and the work is being developed in this direction. Comparing potassium nitrate and ammonium nitrate as sources of nitrogen, the advantage is more frequently with potassium nitrate, though there are some peculiar and striking adjustments which may not be specifically discussed here. It appears, too, that these relations are more or less influenced by temperature and by the concentration of the nutrients.

Another phase of the work upon which investigation has been well initiated is the influence of commercial vitamin products on the carbon and nitrogen metabolism of these organisms. The experiments now in progress are to determine, first of all, whether the vitamins supplied are in any way important in the nutrition of these organisms.

Effects of Certain Sources of Carbon and Nitrogen on the Production of Acid by Fungi, by B. M. Duggar.

After the growth of the organisms in the cultures referred to in the previous section, the H-ion concentration of the remaining culture media (the filtrates from the fungus mats) was examined colorimetrically with a view to the utilization of such data in pointing out, if nothing more, at least the direction of metabolism in respect to acidity or alkalinity of the by-products.

When peptone alone served as a source of both carbon and nitrogen, the H-ion concentration was shifted (by every organism except *Aspergillus niger*) toward alkalinity and generally beyond the neutral point. When peptone and glucose were combined, 8 organisms increased the acidity of the medium, 5 developed an alkaline reaction, and the remainder produced very slight, if any, change. With potassium nitrate and glucose, all the organisms used shifted the reaction in the direction of alkalinity at a temperature of 58° to 61° F. except *Aspergillus niger* and *Botrytis cinerea.* With ammonium nitrate as a source of nitrogen, 11 organisms produced a change towards alkalinity and 6 toward greater acidity.

It is notable that such diversity as referred to above exists in the cultures of these organisms, and the problems involved are doubtless complex. Changes in hydrogen-ion concentration may or may not be significant, and it is early to make any specific assumptions, much less to deduce any general rules; but it is certain that the relative concentration of nitrogen and carbon sources, partial exhaustion of the media, temperature, and other factors are important in determining the reaction of the medium.

Vitamin Notes, by H. W. Fenner.

The investigations of Eykmann, Funk, and others which resulted in the discovery of an unknown essential factor in our food playing a very important rôle in metabolism, and in 1911 named "vitamin" by Funk, have so changed our ideas of the relative value of many of our foods that the subject has become one of great interest, not only to the investigator but to the general public, by reason of its apparent importance both to health and to economic considerations.

All vitamins are derived, either directly or indirectly, from plant life, and up to the present time our inability to easily determine the value in vitamins of the various vegetables and plants, to extract, analyze, and preserve these vitamins, and to determine exactly what they are and their rôle in metabolism has, in our daily routine of work, constantly brought before us questions that seem to be correlated with that of vitamins.

In May of this year, in an attempt to aid in elucidating some of these questions, a series of experiments was started, using albino rats as subjects, investigating particularly the vitamin content of some of the commoner food vegetables, such as tomatoes, carrots, sweet potatoes, etc., and sprouted seeds of wheat and beans. These investigations are still under way.

Many difficulties have been met in arriving at some means of concentrating and preserving the B and C vitamins. At present no procedure has been worked out that is entirely satisfactory, but our records are commencing to show some comparative values in vitamin content and general nutritional value, these values appearing to be considerably at variance with many of our accepted conclusions. However, the time is all too short and the results too indefinite to warrant our making a full report at this time. Undoubtedly, considerable time will be required to form any conclusions that may be considered authentic.

PHYTOGEOGRAPHY AND ECOLOGY.

Vegetation of a Desert Valley, by Forrest Shreve.

Work on the vegetation and physical conditions of the Avra Valley and adjacent areas has been chiefly directed, during the past year, to a study of the several soils which the area presents. Additional mechanical analyses have been made in order to secure a more precise knowledge of the distribution of the soil types, particularly in areas where previously determined relations between soils and vegetation did not seem to hold true. The march of soil-moisture was followed in the various soils through the arid fore-summer of 1921, which was characterized by very low percentages as a result of the deficient rainfall of the winter 1920–21, the moisture in sandy outwash having fallen to 1.5 per cent at 15 cm. by February 1. Measurements of the rate of evaporation from soils in place were made, with results that are in conformity with the physical textures of the soils in question. The temperature of the lightest soil in the area (sandy outwash) and of the heaviest (flood-plain) was followed for two months by soil-thermograph readings at 3 inches. The latter soil showed higher maxima and minima than the former, but in few cases was there more than 5° difference between the stations, located at approximately the same elevation.

Laboratory work was carried on with samples of outwash, sandy outwash, flood-plain, and playa soils, with particular reference to determining their penetrability, the capillary rise of water in them, and the rates of evaporation under laboratory conditions. The results are in conformity with the physical textures of the soils, except in the case of the flood-plain type. This is an adobe soil in which from 22 to 51 per cent, by weight, consists of particles less than 0.01 inch in diameter. Although the mechanical analysis of these soils has not been carried to further refinement, there is doubtless a considerable portion of the finest material that is less than 0.001 inch in diameter, resulting in a very slow rate of penetration and a low rate of evaporation as compared with the other much coarser types of soil. In cans of soil of the four types, which were saturated and allowed to evaporate for 36 days, the graphs representing their behavior ran closely parallel for the outwash, sandy outwash, and playa soils, but the rate of fall was much slower for the flood-plain, and at the end of the period it still contained 6 per cent of the original saturation content.

Determinations were also made of the amount of salts readily dissolved from soil samples by hot water, covering the four types of soil just mentioned and also the coarse outwash, a type which encircles all of the larger hills. The results show the highest percentages of soluble matter for the coarse outwash and the flood-plain—the soils which stand at the two ends of the erosion cycle. The lowest percentages were found in certain samples of outwash, in which there appears to be only one-tenth as much readily soluble matter as in the flood-plain. Special determinations were made on samples from areas in which the vegetation is not in conformity with the texture of the soil, as is so generally the case over the entire area under investigation. In these cases the amount of soluble salts appears to be the determining factor and explains the exceptional vegetation. In view of these results further investigation will be made of areas in which the vegetation differs from that in adjacent locations appearing to have identical soil conditions.

In order to secure a more precise record of the differences in vegetation on the several soils in the Avra Valley and adjacent areas, a census was begun of the plant population on typical areas 10,000 square meters in size. The poorest vegetation, both in the number of species and of individuals, is found on the playa soil, where the average of two areas showed 223 plants of only 4 species. Each plant on this soil has an average space of slightly less than 50 square meters. The richest vegetation, in both species and individuals, is found on the coarse outwash, where there is a total of 1,494 individuals of 16 species. Each plant in this habitat has slightly more than 6 square meters of space. Other areas enumerated showed populations intermediate in size and variety between the playa and coarse-outwash soils. In an outwash area dominated by *covillea*, this plant was found to form 87 per cent of the population, whereas in the coarse-outwash area three of the commonest species formed over 15 per cent each and two others over 10 per cent. These statistics have been confined to the perennial woody plants.

Relation of Slope Exposure to Soil Temperature, by Forrest Shreve.

The universality of the influence of slope exposure in modifying the character of the vegetation, outside of tropical latitudes, indicates that the angle of incidence of the sun's rays is the fundamental determinant of the environmental differences between opposed slopes which face north and south. It would appear that the temperature of the soil is the immediate factor by which differences of insolation affect the other aspects of the environment, such as the rate of water-loss, the warming of the lowest layers of the atmosphere, and the lengthening or shortening of the growing season. During April and May 1921 a series of readings at a depth of 3 inches was taken by the soil thermograph on north and south slopes at 3,000, 4,000, and 5,000 feet in the foothills of the Santa Catalina Mountains, near Tucson. The soil was a closely similar granitic loam in all cases, and the slopes were approximately 15° from the horizontal in each case. Toward the end of the period of observation the maximum soil-temperatures increased with altitude, which confirms similar observations made in former years with soil thermometers. Throughout the period the maximum readings for south-facing slopes were slightly lower than those for north-facing slopes. This result appears to have its only possible explanation in the fact that the late afternoon sun falls on the north-facing slope more directly than on the south-facing slope and, in the absence of a plant covering, causes the already warmed soil to attain a slightly higher temperature in the late afternoon, an explanation which is confirmed on some of the records by the later occurrence of the maximum on the north-facing slopes.

In order to compare the influence of slope exposure on soil-temperature under dissimilar climatic conditions, two soil thermographs were installed on north-facing and south-facing slopes near the sea at a point about 5 miles south of Carmel, California. In order to compare the soil-temperature conditions outside of the fog belt with those close to the sea, a second pair of instruments was installed in the Carmel Valley, 7 miles from the ocean. During June, July, and August the maximum on the coast was 4.1° higher on the south-facing than on the north-facing slope, with a smaller difference in the minima. In the Carmel Valley the maximum was 5.8° higher on the south than on the north slope. These figures indicate that the results secured at Tucson are at least not of universal validity, if, indeed, they are true of steeper slopes in that region.

A comparison of the soil-temperatures on the coast and in the interior at Carmel shows that the maximum during the clear days of June was 11.5° higher at the Carmel Valley station and the minimum 11.1° higher, while during the foggy weeks of July the corresponding figures were 17.7° and 14.6°. In both periods the maxima were from 6° to 8° higher on the north slope in the interior than they were on the south slope on the coast, which is a striking index of the difference between the environmental conditions inside and outside of the coastal fog belt.

A Method for Measurement of Evaporation from Soils in Place, by Forrest Shreve.

In order to determine the amount of water lost by different types of soil and by the same soil at different times, under the natural conditions of surface, wetting, and penetration, a method has been developed and used in connection with field work at Tucson. This is an adaptation of the polymeter method for measuring the transpiration of plants in their natural setting. It consists, essentially, in placing a large bell-jar over a spot which is free from plants, placing under the jar a polymeter calibrated for the range of humidities to be encountered, and reading the initial and final humidities and temperatures over an accurately measured period of time, which should be varied with the speed of the rise in humidity. From the initial and final vapor pressures the amount of water may be calculated which has resulted from evaporation during the period of the observation. Reductions may be made easily into terms of water lost per square meter per hour.

At the relatively low humidities under which the method has been employed (15 to 25 per cent) it is found better to observe the time required for a rise of 10 per cent in humidity, although it is possible to observe the humidity attained at the end of a definite period of time. The principal limitations of the method are the necessity of shading the bell-jar in order to prevent too rapid a rise of temperature, and the inevitable stoppage of any air movement that may be acting at the time to increase evaporation. As all readings are taken under identical conditions in these respects, they serve to compare the evaporation in different soils and at different times in a much more satisfactory manner than the weighing of pans of saturated soil under laboratory conditions and with unnatural surface.

In connection with the work on the physical properties of soils in the Tucson region, determinations have been made on four of the soil types under different conditions of moisture. On April 6, following a rain of 0.56 inch, the following averages were secured, in grams per square meter per hour: flood-plains 0.08, sandy outwash 0.06, outwash 0.05, playa 0.04. Another series of determinations made in the same localities one week later found the flood-plain soil so dry that no rise of the polymeter was registered in 20 minutes. The losses from the other soils were: sandy outwash 0.02, outwash 0.03, playa 0.01.

With accurate precipitation data, and with the determinations of soil-moisture taken in connection with the readings of evaporation, it becomes possible to follow with greater accuracy the history of the water which falls on desert and other soils. The extreme difficulty and uncertainty of measuring the run-off and also the amount of water penetrating the soil to considerable depth makes it important to be able to measure the remaining source of loss by physical agencies, especially since this is the only one of the agencies that it is possible to control in the agricultural management of soils.

History of Growth in a Monterey Pine as read from the Longitudinal Section of the Trunk of a Full-grown Tree, by D. T. MacDougal, H. von Schrenk, and Forrest Shreve.

Early in July 1921, a tree of *Pinus radiata*, selected for size, age, and location, of mature height but still showing excurrent growth, was felled and the trunk cut away on one side of the central axis by a skilled woodsman, so as to expose the pith in a median longitudinal section of the entire trunk. The half log was then cut transversely at intervals of 2 meters. With this material a detailed study has been begun of all the geometrical features of growth in length and diameter, of the relation between growth in diameter at various levels from base to top, of the correlation between growth in height and increase in diameter, of the features accompanying the attainment of mature height, and of the relation between growth and the local climatic conditions. The ease with which all measurements and observations on the cross-sections can be checked and supplemented by reference to the longitudinal surface gives an exceptional opportunity to determine features of growth-behavior which are usually inferred or interpolated from incomplete material.

The tree was 20 meters in height and 40 years old, if a liberal allowance of two years is made for the attainment of the stump height of 10 cm. After felling and determining the age of the tree, it was found that the relation between its age and diameter is such as to place it almost precisely in the mean of a curve of age-diameter relationship which was previously determined from 200 trees by Dr. Shreve. In the last 15 years the tree had grown in height 1.9 meters, and in the last 5 years 34 cm., indicating that it was rapidly approaching the period when a mature flat-topped crown is formed.

In the accompanying table are given the ages and diameters of the trunk at intervals of 2 meters from the stump.

Height of measurement, meters.	Age, years.	Diameter (cm.).
Stump........	38	43.5
2...........	35	36.2
4...........	32	29.0
6...........	31	27.3
8...........	30	27.3
10...........	28	22.5
12...........	26	19.6
14...........	24	17.7
16...........	19	12.2
18...........	15	7.5

It will be seen from these figures that between the heights of 4 and 8 meters the tree was growing at the rate of 2 meters per year, and between the heights of 8 and 14 meters at the rate of 1 meter per year. The diameter growth of the last 5 years, like that in height, has been greatly reduced, while the thickest rings of growth were made in the years which also witnessed the greatest growth in height.

The trunk of this pine was found to exhibit to a marked extent the alternation of thick and thin rings, or "double rings," which is frequently observed in this and other species of pines and presents a serious obstacle to the accurate determination of age by ring count. During the 40 years in which this tree has been growing there had been 14 years in which a small accessory ring was formed toward the close of the season's growth. The nature of the latest of these accessory rings is established with certainty through dendrograph measurements made by MacDougal It occurred in the fall of 1918, following a three-day rain of 5 inches in mid-September, and has been detected in several trees by use of the increment borer and in a large number of stumps.

Carbon-Dioxide-Supplying Power of the Air, by Burton E. Livingston.

It is generally regarded as proved that ordinary land plants receive their carbon from the air in the form of carbon-dioxide. If this be true, as it surely must be, at least in all cases where the transpiration rate is very low, it is at once suggested that the ability of the surrounding air to deliver carbon-dioxide to plant foliage may sometimes, or generally, limit the rate of carbohydrate photosynthesis during strongly sunlit periods. Students of this process have been led to the idea that the carbon-dioxide-supplying power of the air is always of sufficient magnitude to surpass the maximum photosynthetizing power of green leaves, but several studies point to the conclusion that this is not generally true. It is at least highly probable that many kinds of plants might absorb and fix carbon at a more rapid rate if the carbon-dioxide-supplying power of the air were greater than it is. Before this question can be adequately studied it will of course be necessary that we have some quantitative measure of the environmental feature here emphasized, and that we secure some knowledge as to just how this supplying power varies from time to time and how it differs from place to place in nature. Also, whenever it shall have become possible to study ordinary plants under artificially controlled conditions, so that true experimentation with these can finally begin, it will be essential to measure and control the carbon-dioxide-supplying power of the air in the culture chambers and to know how this compares with natural conditions.

With such considerations as these in mind, some preliminary determinations of this dynamic condition of plant environment were made at Tucson in the summer of 1921. The method employed was very simple, following the principles on which the evaporating power of the air, the water-supplying power of the soil, etc., have been studied. A carbon-dioxide-absorbing surface with adequate absorbing power is exposed to the air, and the amount of the gas actually absorbed is taken as a measure of the average supplying power for the period of exposure. Small glass cylinders exposing about 24 sq. cm. of absorbing surface (of a solution of sodium hydroxide) were used, the alkalinity of the absorber solution being determined by titrations before and after each exposure. The results, which are to be regarded as only preliminary, indicate that the carbon-dioxide-supplying power of the air has values ranging from a minimum of about 1.4 grams to a maximum of about 1.4 grams of carbon dioxide per hour and per square meter of absorbing surface. The minimum represents a day-time exposure on the soil surface under tall, dense grass in the experiment grounds of the Desert Laboratory. The maximum represents a night exposure indoors, with rotating table and electric fan.

As in the case of the evaporating power of the air, the carbon-dioxide-supplying power depends upon two component conditions; the partial pressure of the gas (corresponding to the vapor-pressure deficit for evaporation) and the velocity of air-movement over the standard surface. With low average wind velocities the supplying-power values are generally low, while periods of high wind give relatively high values.

Comparative Rates of Water Evaporation from Different Kinds of Surfaces, by Burton E. Livingston.

Earlier studies in atmometry and measurements of plant transpiration have made it empirically clear, as it was already clear on *a priori* grounds, that the rate at which water is vaporized and removed from a surface of liquid water (whether free or held in a solid matrix, such as porous porcelain, cellulose, etc.) is influenced as much by the kind of surface as by the conditions of the surroundings. As has been emphasized in a previous report, the power of the aerial surroundings, at any point, to remove water by evaporation from a liquid surface may be studied quantitatively by means of any form of atmometer that is able to supply new liquid water to the exposed surface as rapidly as drying occurs through evaporation. But the measurements must always be considered as related to the particular form of atmometer used. It is not possible, for example, to calculate evaporation from an open pan of water by means of readings secured with a porous-cup atmometer, etc. This feature makes the study of evaporation as a climatic feature very complex and somewhat more difficult than is the corresponding study of rainfall. To gain more information on this subject, pans of water were employed with several forms of porous-cup and other atmometers in a series of observations made at Tucson in the summer of 1921. The results support the conclusions previously reached, and the white-porcelain sphere remains the most satisfactory form of atmometer for the careful study of the evaporating power of the air, at least aside from the influence of sunshine. For less detailed and less precise studies, open pans of liquid water and non-spherical porous cups have their places, and the Bates cloth-wick atmometer (which was included in the tests here considered) appears to be satisfactory for roughly general comparisons when the evaporating power of the air does not exceed the capacity of the instrument to deliver liquid to the evaporating surfaces as these are exposed through the perforations in the lower plate. The last-named instrument appears to be suitable, as far as its readings are concerned, for the ecological and forestry work for which it was devised.

Plant transpiration is evaporation from water-imbibed cell-walls, and the imbibed water contains significant amounts of dissolved material. It has often been suggested that the rate of plant transpiration may be considerably retarded by high solute concentration in the cell solution, this suggestion being deduced from the fact that such high concentration of a solution is accompanied by high osmotic potential and by lowered vapor tension. It has been pointed out, however, that such concentrations as generally occur in plant tissues, while they may sometimes give osmotic values as high as 20 or 30 atmospheres, can produce only a slight lowering of the vapor pressure of the solutions as compared with water. Although this matter seems quite clear from the physical view-point, some tests with pans of water and of molecular cane-sugar solution were made at Tucson in 1921, to determine the relative evaporation rates of these two liquids when similarly exposed. From these tests it appears that, *in the absence of direct sunshine,* the sugar solution evaporated at a rate less than 10 per cent lower than the rate at which water evaporated under the same conditions. This is in accord with physical theory. But another point was brought out, namely, that when both the pans were *exposed to direct sunshine* the sugar solution evaporated considerably more rapidly than did water. This was doubtless due to an action of the dissolved sugar resulting in the absorption of more radiation than was absorbed by pure water. The dissolved sugar appears to act somewhat like particles of carbon held in suspension. Like a suspension of carbon, the sugar solution becomes warmer than water similarly exposed when both are in sunshine, and evaporation is markedly less rapid from the water. Whether these points are important in the consideration of foliar transpiration as related to sunshine remains to be determined, but they do not seem to have been mentioned in the literature.

In connection with the studies mentioned above, the investigation of the principles concerning the influence of solar radiation on evaporation was continued by means of blackened and white porous-cup atmometers of several forms (radio-atmometers), pans of water, sugar solution, carbon suspension, etc. Sunshine has long been known to be a very important feature in the control of plant transpiration, but its influence on this plant process has never been adequately studied. The investigation just mentioned is directed toward a quantitative knowledge of the influence of solar radiation on the rate of loss of water vapor from plants. A somewhat thorough discussion of this whole problem is planned for the near future.

Inheritance of Teratoid Flowers in Diplacus glutinosus, by Francis E. Lloyd.

A single plant of the perennial shrub *Diplacus glutinosus* with teratoid flowers was found growing a short distance from the Coastal Laboratory in 1915. The character of the abnormalities is as follows:

The sepals were very numerous, and varied from minute subulate bladeless members to narrowly ovate, apiculate, and sometimes downwardly ascidiate and petiolate free sepals; ascending the supporting axis they became more and more united to form partial or entire calices, usually split longitudinally, 3- to (and more usually) 6-merous. The calices numbered 3 to 4, arranged cone-in-cone fashion, the uppermost usually more or less petaloid. Above these there were generally two corollas, entire or split longitudinally, or instead there was frequently a spiral series involving as many as 18 to 21 members, the lowermost being sepaloid, the uppermost petaloid, the whole showing more or less strepsis. Concrescence might also occur between the spiral series and other members, arising either in axillary positions or within, toward the apex of the axis.

The stamens were usually absent (only one case in 36 afforded two perfectly formed anthers but with almost sterile pollen), and those present were either variously fasciated or displayed partial or complete petalody, free or concrescent with the corolla or corolla-spiral; or, again, some degree of pistillody was observed. The pistil was either single and normal or nearly normal, or it might show duplication, with quadrilocular ovary, or it might be monocarpellary, with two placentæ. When supernumerary pistils were present, usually two in number, the ovaries were open and distorted, displaying the more or less imperfect ovules along the margins. In extreme cases the andrœcium and gynœcium were entirely abated, and the axis, with branches from the axils of the corolla lobes, might be proliferate, bearing foliage in whorls, followed by other abnormal flowers. These in all cases were paler in color, more or less virescent, and always notably shorter than normal flowers with respect to the constituent members. The degree of abnormality was less when the plants were young, as would be expected, and earlier in the season than later.

Successful pollinations with pollen from normal plants were made in three instances, in which the pistils were normal. The seed (F_1) was grown at the University of California. The seedlings were transplanted in September 1916 into a bed prepared in an isolated position at the upper end of the Coastal Laboratory garden. Here in 1917 they flowered. These plants were entirely normal. The seed from these interpollinated plants was also grown at Berkeley, and previous to September 1920 had yielded 155 plants, which had flowered. Of these, 122 were normal and 33 abnormal, which produced teratoids of the same character as those observed on the ovulate P_1 plant.

The ratio obtained in F_2 (4 normal to 1 abnormal) may have resulted from the condition of spontaneous pollination permitted, although it was thought that the plants were fairly well isolated. It is sufficiently close, however, to indicate the character of the inheritance.

The culture and observing of the plants at the University of California was possible through the very kind coöperation of Professor E. B. Babcock and Dr. J. L. Collins. The culture is still available there.

DEPARTMENT OF EMBRYOLOGY.*

George L. Streeter, Director.

CYTOLOGY.

It may be well to explain that in tissue-cultures individual growing cells from a bit of explanted embryonic tissue, in making their way into the surrounding medium of clear fluid, stretch themselves out flat and very thin on the lower surface of the glass cover-slip, under which conditions they can be readily examined in the living state with high magnification. This method, which has been perfected in large part by Professor W. H. Lewis and Mrs. M. R. Lewis, of this laboratory, has enabled us to study the cytoplasm and finer anatomy of the cell more intimately than was before possible, and at the same time to introduce experimental procedures and observe the behavior of cells in altered environments and under the influence of various stains and reagents. It is quite likely that the essential structure of a growing cell in tissue-culture is the same as that of similar cells growing normally in the embryo, but the shape of the cell, owing to the flattening-out tendency, usually departs considerably from its natural outlines. On this account we have had much difficulty in identifying the unfamiliar forms exhibited by the cells in cultures. Sufficient progress, however, has now been made in the study of their appearance and behavior to make possible a description of the characteristics of the primary cell types, as seen under these conditions.

Characteristics of Cell-Types in Tissue-Cultures.

It has been found by Professor Lewis that each cell which migrates out of the explant onto the coverslip does so in a manner peculiar to its type. The blood-cells and clasmatocytes pursue very irregular paths, the individual cells retaining their complete independence and rarely adhering together to form a definite pattern. On the other hand, ectodermal and endodermal cells, which always migrate out in the form of a membrane, adhere to their neighbors in more or less even lines. Intermediate between these two extremes are the mesenchymal, endothelial, and smooth-muscle tissues, in which the cells tend to adhere to one another by their processes rather than by their borders, thus forming loose reticuli, the pattern in each case being characteristic for the respective cell-type. Differing from all of these are the characteristic outgrowths of long, multinucleated strands from striated muscle and the long, slender nerve-fibers from the sympathetic and central nervous systems. Both the muscle-strands and the nerve-fibers have a tendency to form anastomising plexuses, those of the nerve-fibers being elaborate and complicated. Once attained, the characteristics of the individual cells and of the cell colonies remain stationary until degeneration of the culture takes place; there is no further differentiation except cell division, which is frequent. There is an interesting resemblance between the reticulum of smooth muscle and that of endothelium, in that under conditions of fixation they both exhibit fibrillæ. This indicates the presence of a considerable amount of contractile substance in endothelium and provides an anatomical basis for the contraction of capillaries.

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The completed study of Dr. Ruth S. Lynch, on the cultivation *in vitro* of liver cells of chick embryos, has been published since our last report and constitutes a description of another distinct cell-type. Dr. Lynch succeeded in obtaining membrane-like outgrowths of liver cells up to 27 micra wide. In her publication she has carefully described and illustrated the histological character of these cultures and the manner of growth and degeneration of the liver cells and the associated tissues.

Cytoplasmic Granules.

Living protoplasm is characterized by the presence of a variety of cytoplasmic granulations concerning whose composition and function we know very little; that some of them play a fundamental part in the activity of the cell, however, there can be no doubt. There are (1) the specific granules normally present in and characteristic for certain cells, such as the granules of leucocytes, the large granules of eosinophile cells, secretion granules, and, widely differing from these, the specific pigment granules of the pigmented cells and the fat globules and granules of fat cells; (2) the mitochondrial granular or rod-shaped bodies which are present in all protoplasm and which are apparently concerned with some fundamental process common to all cells; (3) a newly recognized group of granules found in cultures grown in media containing white of egg, to which reference will be made later; (4) a group of granules and associated vacuoles which stain selectively with neutral red.

In the Year Book for 1919 I referred to a study by Professor Lewis, in which he described the occurrence and behavior of neutral-red granules and vacuoles in degenerating fibroblasts, reaching the conclusion that they constitute a part of the process of cell degeneration. During the past year an additional study on the origin and functional activity of these neutral-red granules and vacuoles has been published by Miss R. E. Prigosen. Miss Prigosen adopted the method of making film preparations of living subcutaneous connective tissue of 8 to 17 day chick embryos and placing them under abnormal conditions, such as in media to which neutral red had been added or from which oxygen was excluded. The cells were then studied until their ultimate death. These experiments fully confirmed the previous observations of Dr. Lewis. Neutral-red granules and vacuoles accumulated in the cytoplasm of the fibroblasts in proportion to the degree of degeneration of the cell. It has been maintained by some that these bodies correspond to food vacuoles. Miss Prigosen rules out any question of phagocytosis or simple intracellular accumulation of dye, and finds the staining reaction of these vacuoles (yellow or brick-red) to be quite different from that exhibited by the food vacuoles (rose tint).

Another method of producing degeneration vacuoles has been found by Mrs. Margaret R. Lewis. Advantage was taken of the fact that dextrose is an essential part of the medium for tissue culture and that its absence results in a disturbance in the normal metabolism of the cell. Mrs. Lewis was thus able to produce degeneration vacuoles by decreasing the dextrose in the culture medium. In media lacking dextrose the cells showed numerous vacuoles in 24 to 48 hours; in media containing 0.25 per cent dextrose, vacuolization, degeneration, and death of the cells were retarded several days; while in media containing from 0.5 to 1 per cent dextrose the cells continued in an apparently healthy condition for as long as two or three weeks without the appearance of vacuoles.

From a study of the effects of egg white introduced into the medium of a culture of connective tissue, Mrs. Lewis has been able to differentiate a type of cell granule which she terms the "*al*" granule, mention of which was made in a preceding paragraph. These granules are large, rounded, somewhat refractive bodies formed within the cytoplasm of connective-tissue cells. When stained with eosin they resemble the colloid or hyaline droplets seen in renal epithelium under pathological conditions, and when stained with iron hematoxylin the cells containing them resemble cells undergoing active secretion. The *al* granules, both in living and fixed material, are easily distinguishable from neutral-red granules, with which they may exist side by side in degenerating cultures. They differ also from pigment granules and certain secretion granules, in that they are less frequently found collected around the centrosphere. The processes of the cells are always free from these *al* granules. Cells were found to divide by mitosis even when full of the granules, whereas mitotic division is rarely seen in the presence of degeneration vacuoles. There is some variation in their size, but in most cases they are much larger than either mitochondrial bodies or neutral-red granules. They are not readily stained by vital dyes, although they show a slight reaction to neutral red. In fixed preparations stained with iron hematoxylin they appear in various shades, from dense black to gray. When embryonic connective tissue was placed in egg albumin, the cells grew out in the medium much as in normal cultures, and at the end of 16 hours they contained many of the *al* granules, the maximum number being reached at 24 hours. Owing to the toxicity of the medium, few of these cultures survived more than five days, as contrasted with normal cultures, which live for two weeks or more. When diluted albumin was used the phenomenon was retarded. When cultures were started in Locke-Lewis solution and transferred to egg albumin, the *al* granules did not appear for several hours, but after 20 hours these bodies were about as abundant and as large as those in cells of cultures explanted directly into egg albumin. In using the term "*al*" granules, Mrs. Lewis does not mean to signify that they consist of albumin, but only that they are the invariable result of the presence of albumin in the environment of the cells. As for the factors concerned in the formation of the *al* granules, Mrs. Lewis points out that there must be egg albumin in the medium in which the tissue is growing; a solution of peptone will not suffice. Furthermore, it is evident that the phenomenon is associated with conditions that are unfavorable to the life of the cell. Whether it is a process of phagocytic nature or due to some change in the cell membrane which permits the entrance of some material normally excluded or prevents certain substances from passing out of the cell, remains to be determined.

Pigment-Producing and Pigment-Carrying Cells.

Heretofore the pathologist has had no adequate criteria for determining whether, in a given pigmented cell, the pigment was formed within it or had been ingested. The importance of obtaining some means of distinguishing between the pigment-producing cell and pigment-carrying cell will be appreciated when it is recalled that the presence of the former in a new growth is an indication of a malignant process, whereas the latter may mean nothing more than the phagocytosis of broken-down blood-elements. By means of tissue-culture methods, Mr. David T. Smith has obtained criteria which apparently enable one to accurately distinguish between these two varieties of pigment granules. In the first place, he made careful observations on the origin and development of melanin pigment in the retina of the embryo chick, studied *in vivo* and *in vitro*. In cultures, the pigment cells migrate out in the form of a thin membrane, thus offering an excellent opportunity to observe the behavior of the cytoplasmic granules in the living state. From such preparations it was found that pigment granules are neither extrusions from the nucleus nor converted mitochondria, as has been frequently maintained, but arise in the cytoplasm of the cell as small, colorless or gray granules, which appear at about 42 hours' incubation. They gradually increase in size, number, and depth of color until, at 17 days, the cell is filled with black rod-shaped granules of uniform size. There is thus the stage of colorless chromogen, followed by the stage of color production in the chromogen. When formed, the pigment granules are very stable and are not destroyed by strong acids. They move about the cell with a characteristic swift, jerky motion and remain discrete, showing no tendency to clump together in vacuoles.

Having ascertained the appearance and behavior of the granules of the true pigment cell, Mr. Smith then studied the phenomenon of ingestion of pigment granules by the cells of various embryonic chick tissues grown in Locke-Lewis solution. It was found that melanin pigment obtained from the retina of the chick, pig, dog, and new-born child is readily ingested in tissue-cultures of chick embryos by clasmatocytes, fibroblasts, endothelial cells, white blood-cells, and cells from the lung, liver, kidney, intestine, and amnion. On the other hand, it is not ingested by the peripheral-nerve cells, striated-muscle cells, or red blood-cells. When free in the culture fluid, the pigment granules, in addition to progressing from place to place, exhibit a characteristic Brownian movement; when attached to the cell-wall they become motionless; after passing into the cytoplasm they exhibit the same jerky motion noted in pigment granules in their native cells, until finally a vacuole is developed about them, whereupon they revert to Brownian motion. The manner in which the granules are ingested is of interest. They are not engulfed by the throwing out of pseudopodia, as has been described for the amœba. When the granule comes in contact with the cell-wall, it is simply drawn into the interior as if by capillary attraction, the result apparently of a local modification of the cell-membrane. It is of interest also to note that the pigment granule, on entering a cell, is not taken into a preformed vacuole, nor does a vacuole immediately form about it; only after it has been in the cytoplasm for some time is the vacuole formed. Once within the vacuole the granule swells, breaks up into fragments, and is ultimately reduced to minute particles of débris. It is the clumping together of the granules into masses of irregular size and shape, their inclosure in vacuoles, and their degeneration into débris that distinguish the ingested pigment from that contained in true pigment-producing cells.

The phenomenon of phagocytosis has also been studied by Dr. G. B. Wislocki. Taking advantage of the fact that the endothelial and reticular cells in bone-marrow tend to phagocytize and retain solid particles brought to them by the circulating blood, Dr. Wislocki succeeded, by means of the thick deposit of pigment that can be thus produced in the marrow, in demonstrating the distribution of the marrow throughout the skeletons of new-born and adult rabbits, a detailed description of which is given in his paper. His method consisted of the injection of carbon particles (dilute india-ink) into the blood-stream and a few days later sacrificing the animal, removing the viscera, and rendering the remaining tissues of the body transparent by the Spalteholz clearing method. After this procedure the blackened bone-marrow could be seen everywhere accurately delineated from the surrounding structures. This method should prove of value in studies of bone development, both normal and where disturbances of development and growth of bone are produced experimentally. Dr. Wislocki found that differences exist in bone-marrow cells of the different mammalia as regards their ability to phagocytize and store particles of carbon. In the cat and dog the phagocytosed carbon is confined to the liver, spleen, and lungs; in the guinea-pig the bone-marrow also takes up some of it; while in the rabbit it is found distributed equally between the liver, lungs, spleen, and bone-marrow.

Cultures of Human Lymph-Glands.

Dr. Lewis and Dr. L. T. Webster have made a series of successful plasma cultures from normal and pathological lymph-nodes obtained by operation at the Johns Hopkins Hospital. Autoplasma and homoplasma were used as media, the outgrowths in the two being about the same, except that migration took place slightly earlier in autoplasma. The investigators were able to demonstrate in this way that in tissue cultures maintained at body temperature the lymphocytes of both normal and pathological lymph-nodes are actively amœboid and migrate in a definite and characteristic manner for several days. The establishment of this point is of considerable clinical importance, in that it offers an explanation for the local accumulation of lymphoid cells such as occurs in lymphatic leukæmia. Furthermore, it seems probable that lympho-sarcoma is not a neoplasm, but a response on the part of the lymphocytes to a localized chemotactic disease-causing agent.

The migration of the lymphocytes precedes that of the larger wandering cells and giant cells, beginning within an hour or two after the culture has been placed in the warm box. This migration continues for two or more days until all the living lymphocytes have left the explant. They migrate out into the plasma clot more readily than along the cover-slip and at a maximum rate of 0.03 mm. per minute. The path of migration is irregular, but in general it is away from the explant. The cells may be deflected from their course by coming in contact with other cells or with fibrous threads. The migration may be interrupted by rest periods, during which the lymphocytes assume a rounded form. While moving they are elongated, with the nucleus at or near the forward-moving end. The nucleus, though plastic and continually changing shape, forms the broadest part of the cell. The scant amœboid cytoplasm in front of it is homogeneous and free of granules. The bulk of the cytoplasm is behind the nucleus and forms a finger-shaped process containing mitochondria and granules. The striking polarity exhibited by the moving cell may be recognized also in the more rounded resting-stage.

In connection with their observations on the migration of lymphocytes, Lewis and Webster noted in these cultures the presence of large giant cells closely resembling those found in tuberculous nodes. They appeared to form within the explant and to migrate out into the plasma clot afterward. In structure and appearance they were practically identical with the large wandering cells that were present in great abundance in nearly all of the cultures, differing only in their larger size and greater number of nuclei. They usually appeared about the second or third day, after the lymphocytes, polymorphonuclear leucocytes, and wandering cells had left the explant. They migrated out from explants from normal and tuberculous nodes, nodes from acute and chronic lymphadenitis, from Hodgkin's disease, and from a metastatic sarcoma. They were most abundant, however, in cultures from tuberculous nodes. These giant cells were conspicuous for their large accumulation of bright-green fat globules and for their numerous nuclei, which ranged in number from 2 to 60, the usual number being 10 to 20. Their movements were slow and deliberate, but there was some shifting, both of the cells themselves and of the nuclei. When flattened out on the cover-glass, each cell was seen to contain a central granular area which stained avidly with neutral red in the culture and with eosin in the fixed material. Since neutral red is probably taken up only by the non-living cytoplasmic inclusions, this central area must be considered as non-living, probably partly digested food and waste products, or perhaps segregated foreign substances.

Surrounding this central area there was a zone of fat-globules in which were embedded the nuclei. Scattered about this zone, or mingling with the peripheral fat-globules, were the thread-like mitochondria, the whole being surrounded by a clear, more or less homogeneous ectoplasm. Within the central area there could sometimes be observed what appeared to be a centrosphere, but no centriole could be made out in any of the cells, in either the living or fixed material. The nuclei exhibited a peculiar and significant horseshoe-like arrangement about the equator of the central area, which can be best explained on the hypothesis that giant cells arise from large wandering cells by amitotic division of the nuclei without division of the cytoplasm. Only one clear case was seen, however, of amitotic nuclear division. On the other hand, there was no evidence that these giant cells arise by fusion of large mononuclear cells.

Effect of Potassium Permanganate on Mesenchyme Cells.

It has been found by Dr. Lewis that, by using the strong oxidizing reagent potassium permanganate, certain reactions can be produced in mesenchyme cells of tissue-cultures which closely resemble some of the features of mitosis, and apparently the two processes have something in common. Weak solutions (1:40,000 and 1:80,000) of the reagent were used so that the changes could be followed, death of the cell resulting in about half an hour. In the nucleus the chromatin material was contracted into a dense, deeply staining mass and the nuclear sap was expelled in the form of clear fluid vacuoles, the process resembling the segregation of chromatin material and nuclear sap in mitosis. In both potassium experiments and mitosis the mitochondria became broken up into rods and granules and transformed into vesicles. In both, also, there was condensation of the cytoplasm. It was found that the centrosphere was not affected; this, together with the fact that the centrosphere enlarges in cell degeneration, may be taken as evidence that this structure is not the dynamic center of the cell, as has been previously maintained, but is rather to be looked upon as a degenerating area.

CENTRAL NERVOUS SYSTEM AND SPECIAL SENSE-ORGANS.

The Fetal Brain.

During the winter of 1920, spent in this laboratory as a guest, Professor George B. Jenkins utilized our embryological collection and records for determining the relative weight and volume of the component parts of the brain of the human embryo as found at different stages of development. Dr. Jenkins's work has now been completed and published. To represent the first half of intrauterine life he selected 8 specimens (the youngest being 4.3 mm. long) which had been prepared in serial sections. Models of the brains were made with wax plates and these were subdivided into 11 component parts and the weight and volume and the subdivisions determined. During the second half of pregnancy the relative volume of the different parts remains more constant, so that 2 specimens were sufficient to cover this period and the brains were large enough to dissect into parts corresponding to the younger specimens. The weight and volume of each part could therefore be determined directly without resort to serial sections and modeling. In this manner Dr. Jenkins was able to trace the original predominance of the primary centers and their gradual loss in relative volume coincident with the growth of the secondary centers. It is of interest to note that in a 4-mm. embryo the cerebrum constitutes only 7 per cent of the volume of the brain, whereas in the later fetal stages it forms nearly 90 per cent. In the younger stages about one-half of the brain volume is accounted for by the nuclei of origin of the cranial nerves and their associated fibers.

Rudimentary Head Cavity.

In studying some of our younger human embryos, Dr. Joseph L. Shellshear, of the University College, London, succeeded in identifying, in the neighborhood of the glossopharyngeal ganglion, a cavity of the axial mesoderm which appears to be homologous with the head cavities that give origin to the muscles of the eye. Arising from the cavity is a clump of spindle-shaped cells, continuous with and similar to the group mesial and posterior to the vagus nerve, which Dr. Shellshear interprets as the migrating elements of the hypoglossal musculature. Through the aid of the Rockefeller Foundation, it was possible for Dr. Shellshear to spend several months of the past winter with us as a guest.

SUBARACHNOID SPACES.

The series of studies carried out during the past few years by Professor Lewis H. Weed and other workers associated with him has given us a more definite and concise conception of the morphology and behavior of the cells lining the subarachnoid space, which were previously little understood. In a shorter account, referred to in the last Year Book, Dr. Weed described the changes which these cells undergo with increasing age of the animal, exhibiting in young adult and old cats characteristic proliferations. It will also be recalled that in his monograph on the histogenesis of the subarachnoid space he described the development of these cells in the embryo pig. During the past year his observations have been extended and brought together into a complete account, in which he assembles all his previous results. This important paper presents, in the first place, the normal form and disposition of the subarachnoid cells, both in the embryo and in the adult. Dr. Weed follows this with a description of the changes in form which they undergo under physiological activity in response to exposure to various stimulating and destructive substances, including infective processes. Like the mesothelial cells of the peritoneum, in the normal state they spread out in a thin and usually single layer, lining more or less completely the arachnoid membrane and its trabeculæ. Under the stimulus of injected matter, however, the cells enlarge, become phagocytic, and may break away from their attachments and move about freely as macrophages in the subarachnoid space. Localized proliferations of arachnoid cells, both in man and in laboratory animals, had been previously observed without being understood. As a result of Dr. Weed's observations, it is now clear that they are conditioned by age. They are absent in the young, are usually present in the adult, and increase with advancing age. In tracing their ultimate fate, it is found that they reach a limited size, after which they either persist or undergo degeneration with subsequent infiltration of calcareous material. Occasionally, they apparently become converted into true endotheliomata.

Dr. Weed and Dr. Hughson have been able to demonstrate experimentally that the cranium and vertebral canal, within which the central nervous system lies, are so constituted as to form a closed and unyielding chamber and thus, by the administration of hypotonic solutions, it is possible to produce a negative pressure in the cerebrospinal fluid. A preliminary account of these experiments has been given and the complete report is in process of publication.

MEMBRANOUS LABYRINTH.

In the course of some experiments carried out several years ago with amphibian larvæ, I discovered that the cells constituting the ear-vesicle are specialized very early and that, when transplanted to an abnormal environment, they continue to differentiate in the usual way into a recognizable labyrinth. Even fragments were found to develop independently of the rest of the vesicle, and an individual part, such as the endolymphatic appendage, might be quite normal in cases where the remainder of the labyrinth was very abnormal. It was further found that the developmental independence of the vesicles extends to differences existing between a right-sided and a left-sided organ. The dextral or sinistral character of the ear-vesicle is not controlled by its environment but by the intrinsic character of its own constituent cells, and a left ear-vesicle, when transplanted to the right side, develops into a labyrinth having all the characteristics of a left-sided organ. It was found, however, that the ear-vesicle, though capable of this marked power of self-differentiation, was not in all respects independent of the surrounding structures. The posture of the fully developed labyrinth and the position of its canals were found to be controlled by the environment. Deliberate rotation of the ear-vesicle into abnormal positions, and even its transplantation to the opposite side of the body, resulted in a labyrinth possessing a normal attitude with reference to the brain, ganglion masses, and the surface of the body. Regardless of the manner of its displacement at the time of the operation, the labyrinth seemed always to correct its position, even to the extent of complete rotation. The existence of a postural influence of this kind introduces a new factor in organogenesis, concerning the nature of which we know very little. It forces the conclusion that the labyrinth does not develop inertly in the position in which its rudiment first lies, subject only to mechanical stresses of the adjacent structures, but that we must also take into consideration an autostatic tendency inherent in the vesicle itself, by virtue of which it maintains and accurately adjusts its position during the course of development.

In substantiation of the above conclusion, I have been able to show during the past year, from a study of normal material, that not only does this adjustment of position occur under artificial conditions of experiment, but that in the ordinary course of development the ear-vesicle undergoes a recognizable migration or change of position, moving from the point of its original attachment to the skin to a more median and dorsal location, where it adjusts itself closely against the side of the brain in a definite attitude.

Other experiments on the ear-vesicle of amphibian larvæ were made by Professor C. Ogawa, while a guest of this laboratory, in order to determine, if possible, how soon the ear-vesicle rights itself after an experimental displacement; whether it slips back into its normal position immediately after the operation or later, after the wound is healed. His observations indicate the latter to be the case. There was no evidence of rotation during the first 3 hours, at the end of which time the wound had entirely healed. Specimens examined between 16 and 34 hours after operation, when the labyrinth is still a simple oval sac without canals, showed that rotation had occurred. Dr. Ogawa also demonstrated that an ear-vesicle may be transplanted from one species to another (*Amblystoma* to *Rana* or vice versa) and that, when placed in an inverted position, it rotates into the normal posture by the end of the second week. The environmental influence in the determination of posture is therefore effective even for the ear-vesicles of species of a different order.

In my own experiments, and in earlier ones of Dr. Ogawa, the inversion of the vesicle at the time of operation was obtained by rotation about the vertical axis, with the result that the lateral concave surface was placed toward the brain. In his recent observations Dr. Ogawa found that when the vesicle was rotated about the transverse axis, recovery of position failed to take place in nearly half of the cases, although the technique was otherwise the same as previously employed. He does not regard this decreased tendency to rotation as due to the difference in inversion axis, but more probably to the fact that where the rotation is about the transverse axis the open side of the vesicle is left in contact with the healing wound, with which it may become sufficiently adherent to interfere with rotation.

DIGESTIVE TRACT AND VASCULAR SYSTEM.

The interesting development of the gastro-intestinal tract of the opossum has been studied by Dr. C. H. Heuser. In this non-placental animal the intrauterine period lasts only 13 days; 5 days after the beginning of segmentation the immature animal is expelled from the uterus and, by its own efforts, secures attachment to a teat in the maternal pouch, where its development is completed. Nutrition is made possible by the precocious growth and differentiation of the gastro-intestinal tract, particularly the upper part of the small intestine. By means of models and the study of sections, Dr. Heuser has been able to trace the phenomenal alterations which this system undergoes in the few days preceding birth and the first few days in the pouch, whereby the rudimentary foregut, hindgut, and midgut become converted into a series of structures capable of assimilating milk. Only those portions of the body that play an accessory rôle, such as the sucking mechanism and the forward extremities, take part in this precocious growth.

In our report of last year reference was made to the observations of Dr. R. S. Cunningham on the striking morphological changes and phagocytic activity shown by the peritoneal mesothelium in response to intraperitoneal injections of granular suspensions and laked blood. The clinical importance of being able to use the peritoneal cavity as a route for the administration of therapeutic agents has led Dr. Cunningham to continue his studies on peritoneal mesothelium, with the view of determining particularly the degree to which such injections are injurious or harmless to the peritoneum. From experiments carried out with solutions of dextrose, he finds that this particular substance can be injected without injury to the mesothelium. The changes which occur over the diaphragm, spleen, and omentum are in the nature of a stimulated proliferation; the swollen cells either return to normal or are replaced by other cells within a few days.

The more conspicuous morphological changes by which the branchial vascular arches are converted into the permanent vessels of the adult are already known, but before the factors that bring them about can be understood a knowledge of the detailed development becomes necessary. Our large collection of embryos and the associated facilities of the Department have made it possible to undertake a more careful study of these vascular transformations. Dr. E. G. Congdon, of Leland Stanford University, is at present engaged in preparing a series of reconstructions of the aortic arches as they are found in the human embryo. Dr. Heuser has studied the same structures in the embryo pig and, by using injection and clearing methods, has been able to make important observations. A preliminary account of these has already been published and the complete description is now in course of preparation.

Using some of the improved methods of injecting blood-vessels, Professor F. R. Sabin has made a histological study of the process of repair in end-to-end intestinal anastomoses. In addition to making observations on the healing of the mucosa and the changes in the smooth muscle, she was able to follow the regeneration of the blood-vessels, a process which has a direct bearing on the fundamental problem of the origin and differentiation of angioblasts. Dr. Sabin has found that the regeneration of vessels is limited to specific areas and that the growth of new vessels is preceded by a change in the endothelium of the old vessels in the nature of a return to the original angioblastic type, with a great multiplication of endothelial nuclei. From such transformed vessels solid masses of angioblasts grow out, acquire a lumen through liquefaction of their cytoplasm, and, after passing through a capillary stage, become arteries and veins. The picture corresponds closely to the origin of blood-vessels, described by Dr. Sabin in the living blastoderm of the chick.

UROGENITAL SYSTEM.

The development of the external genitalia in the human embryo has been studied by Professor M. H. Spaulding, who succeeded in finding criteria, based on the morphology of these structures, by which one can recognize sex at an earlier period than has heretofore been possible. He finds no evidence of the existence of an indifferent period through which all embryos were supposed to pass before assuming definite male or female characteristics. The younger embryos show constant differences in the form of the phallus and from the earliest differentiation of the genital tubercle they can be divided into two groups. This division is based upon the marked difference in the length of the urethral groove. This seems to be quite constant and without intergradations; it can be traced backward from the older fetuses, in which the sex can be clearly recognized, to the younger stages, which heretofore have been included in the so-called "indifferent" period. In one group the urethral groove extends from the base of the phallus nearly to the apex of the glans; these embryos are regarded by Mr. Spaulding as males. Those of the second group, in which the groove is shorter and terminates proximal to the region of the glans, are considered by him to be females. Mr. Spaulding's finished paper is accompanied by drawings of models and photographs of actual specimens which represent clearly the morphological changes exhibited by the phallus at each stage of its development. These illustrations should prove of great practical value to those who have occasion to determine the sex of embryos at early periods.

Investigations concerning the morphology of the urinary organs in man have been made by Dr. F. P. Johnson and Dr. M. B. Wesson, of the Brady Urological Institute. The former has studied the development of the urethra and its associated glands, the latter has investigated the embryology of the sphincter muscles at the neck and base of the bladder. The determination of the finer anatomy of these structures has proved to be a matter of considerable clinical importance, and these investigators, by carefully working out the architecture of the early and simpler stages, have provided the necessary groundwork for the understanding of the anatomy in the adult.

Dr. Johnson's study begins with embryos of 55 mm. crown-rump length and follows the development of the urethra to term. Models were made from serial sections of selected stages. By comparing the models with the serial sections, it was possible to determine the number and distribution of the small urethral glands and the formation and consistency of the mucosal folds. Observations were also made on the development of the prostatic glands and Cowper's glands, and upon the formation of the prepuce. In the cleavage of its epithelium, the latter presents an interesting problem which still remains to be solved.

It is shown by Dr. Wesson's study that there does not exist at the vesicle orifice a simple sphincter muscle, as had been generally supposed. Instead, we are dealing with loops of muscular fibers which arise from and are closely connected with the longitudinal and circular muscle-coats of the bladder and, extending down, partially encircle the upper end of the urethra. As regards the trigonal muscle, Dr. Wesson shows that its origin and nervous control are different from those of the rest of the bladder musculature and that it is probably independent in its contraction and relaxation. Embryologically, it is of mesodermal origin, whereas the fundus is of ectodermal origin. Certain definable muscular structures about the neck of the bladder, which have hitherto not been recognized, such as the external and internal arcuate muscles of the vesicle orifice, are described by Dr. Wesson. With anatomical data of this character we may expect to arrive at a satisfactory explanation for the various phenomena of micturition.

Cyclic Changes in Ovary and Uterus.

An important contribution to our knowledge regarding the changes in the mammalian ovary and uterus during the successive events of the reproductive cycle has been made by Dr. G. W. Corner. Through the cooperation of the manager of a large piggery, operated as a garbage disposal plant for the City of Baltimore, Dr. Corner was able to obtain the internal genitalia of pregnant and non-pregnant pigs in which the œstrous period had been observed at all stages of the cycle. From a histological study of this material he has correlated the anatomical changes in the uterus and ovary that underlie ovulation and the mechanism of implantation. Of the various domestic mammals, the pig possesses certain advantages for the study of the reproductive cycle and reduces the problem to the simplest possible terms. The œstrus is periodic, frequent, and conspicuous; ovulation is spontaneous; the litters are large; the ovaries are uncomplicated as compared with those of rodents; and finally, the uterine mucosa is of the nondeciduate type, with a simple, diffuse placenta. Dr. Corner's observations have been published in three separate communications, from one of which I am reproducing a diagram showing the periodic growth of the ovarian follicles and the consequent formation and regression of the corpora lutea. (See fig. 1.)

It will be seen that the cycle is 21 days in length and that ovulation occurs during œstrus. It is also of interest to note that the corpus luteum remains in full development from the seventh to the fifteenth day, long enough to cover the period of attachment of the embryos. If no embryos are present, the corpora lutea degenerate at about the fifteenth day. It has been found by Dr. Corner that during the growth period of the corpus luteum the uterus undergoes histological changes which culminate, at the eighth to tenth day, in marked epithelial activity, with the appearance of an active serous secretion. At this time the embryos, in case the ova are fertilized, are still unattached and are being shifted into position for implantation. From the tenth to the fifteenth day (the period of implantation) further changes in the cells take place, by which the epithelium assumes the state characteristic of pregnancy at the implantation stage. If no embryos are present the same changes occur, but they subside after the fifteenth day, the uterine mucosa undergoing a slow reversion to the œstrous type. These histological changes undoubtedly have a functional value which readily suggests itself, but which remains to be established. It is clear, however, that in the sow the uterine cycle includes an upbuilding of the mucosa, presumably under control of the corpora lutea, which is favorable to successful implantation. Each act of ovulation is thus accompanied and followed by uterine changes which either go on to placenta formation or (in the absence of embryos) subside, as do the corpora lutea, in preparation for a new ovulation.

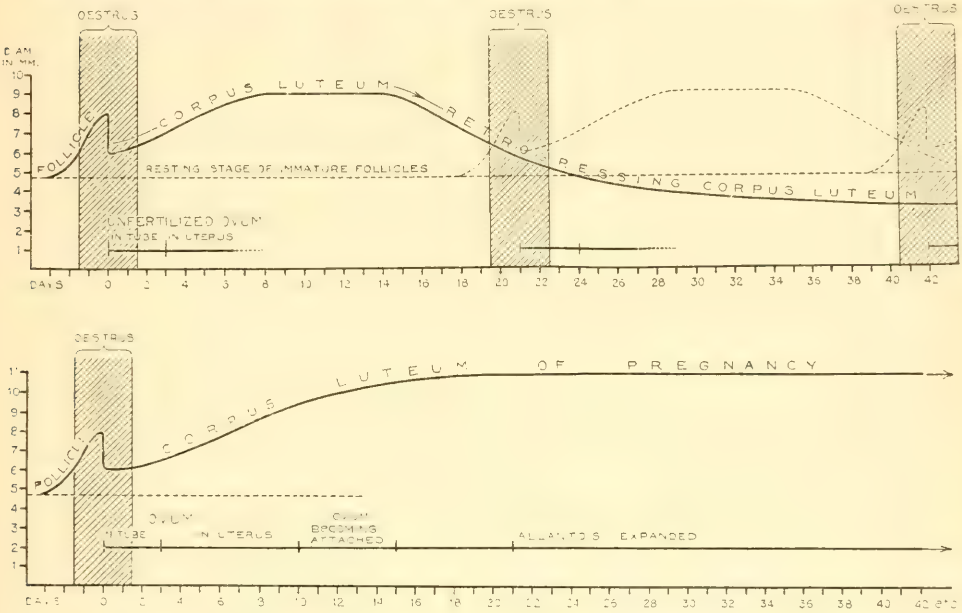

FIG. 1.—Diagram prepared by Dr. Corner showing the cyclic changes in the ovary of the pregnant and non-pregnant sow.

Working on an allied investigation, Dr. Corner has found clear evidence that the ovum of the pig, in passing from the ovary to the site of implantation, very frequently migrates through the uterine horn of its own side and the connecting body of the uterus to the opposite horn, where it becomes definitely implanted. This study was made possible through the cooperation of the Station for Experimental Evolution, where facilities were provided for the examination of a large number of uteri and ovaries from recently slaughtered sows. If one records the number of corpora lutea in a large series of pregnant animals, it will be found that very commonly there are more in one ovary than in the other, whereas in the same animal the embryos tend to be evenly distributed in the two uterine horns. A tabulation of 500 pregnant sows indicates that in about one-third of them there must have occurred a migration of one or more ova across the midline. On the other hand, in sows that had recently ovulated (within three days), and where the ova were en route through the Fallopian tubes, it was found that in at least 96 per cent of the cases there were the same number of ova in the tube as there were discharged follicles on that side, indicating that ova pass directly into the homolateral tube and that external migration to the tube of the opposite side is rare or non-existent. These findings make it clearly evident that internal migration of the fertilized ovum is of common occurrence in the sow.

Permeability of the Placenta.

The placenta may be spoken of as a cellular membrane separating the circulation of the mother from that of the fetus, and its permeability constitutes one of the main factors in fetal metabolism. The problem of placental permeability is as complicated as it is fundamental; it extends from the general problem of the permeability of the cell and the resistance of membranes to the question of the specific ability of the placenta as an organ to select, change, and perhaps synthesize materials needed for the nourishment of the fetus. As a restricted phase of this problem, Dr. R. S. Cunningham has investigated the fluid and salt interchanges between mother and fetus. Selecting cats in the later stages of pregnancy, he injected into the venous system balanced solutions of potassium ferrocyanide and iron ammonium citrate. Owing to the fact that these salts can be precipitated as Prussian blue, they possess the advantage of being easily followed, both in the route traversed and their ultimate location. It was found that the maternal endothelium is easily permeable to both salts, as is also the fetal endothelium. The fetal ectoderm, however, reacts differently to the two salts, in terms of both permeability and length of time required. In experiments of short duration no trace of either sodium ferrocyanide or iron ammonium citrate was present in the amniotic fluid, fetal urine, or tissue extract. In those of longer duration sodium ferrocyanide was found in the fetal urine and amniotic fluid, but in none of the experiments could the slightest trace of iron ammonium citrate be demonstrated in the fetal tissues. Examined histologically, the placenta in the shorter experiments showed Prussian blue in the maternal endothelium, but none within the ectoderm. In the experiments of longer duration blue granules had partially penetrated the ectodermal layer but were not present in the fetal endothelium. In other words, sodium ferrocyanide penetrates through the entire placenta and is soon detected in the fetal urine, whereas iron ammonium citrate is arrested in the ectodermal layer and never reaches the fetal capillaries. There are several reasons to suppose that this selective behavior on the part of the placental ectoderm is based on other factors than osmosis and diffusion, thus suggesting further lines of investigation.

The problem of placental permeability has been approached in a somewhat different way by Dr. G. B. Wislocki, namely, by the injection of colloidal dyes into the venous system of pregnant cats, guinea-pigs, and rabbits, and into the amniotic cavities of the fetuses, the fate of the dye being subsequently determined by a histological study of the maternal and fetal parts of the various animals. It was found that, when trypan blue or pyrrol blue are injected intravenously into the pregnant animal, they reach the placenta and are absorbed and stored in the form of granules in the chorionic ectoderm. In the guinea-pig and rabbit, traces of the colloid may pass into the amniotic fluid, as has been described for the mouse and rat, and may even slightly stain the fetus. In the cat, however, these substances are not transmitted, even in traces, to the amniotic fluid or to the fetus. This difference in behavior is explained by Dr. Wislocki on comparative anatomical grounds, differences of architecture making the placenta of the carnivore less permeable than that of the rodent. It was found that vital dyes are also absorbed and concentrated in granules in the cytoplasm of the cells of the vitelline membrane, which in rodents forms the outermost fetal covering.

When colloidal dyes are injected into the amniotic cavity of the guinea-pig and cat during the second half of pregnancy, they are absorbed in three ways: (1) through the gastro-intestinal tract, (2) through the respiratory tract, and (3) by diffusion through the amniotic membrane. The fetus becomes vitally stained, but none of the colloidal material passes from the fetal into the maternal circulation. The chief depositories of the dye in the fetus and membranes are the endothelial cells lining the hepatic sinuses, the epithelium of the renal convoluted tubules, the amniotic epithelium, and the endothelial cells of the placental capillaries. The endodermal cells of the yolk-sac are also extremely phagocytic toward vital dyes.

The behavior of the placenta toward a particulate substance, such as carbon granules of india ink, injected into the maternal circulation, is quite different from its behavior toward colloids. Dr. Wislocki administered intravenously a filtered solution of india ink into a series of pregnant dogs, cats, rabbits, and guinea-pigs, and found that neither the chorionic epithelium nor the placental endothelium appears to have the power of absorbing or phagocytizing granules as coarse as this. The limit of size of the particles which they are capable of taking up seems to lie somewhere between that of a coarse suspension, such as india ink, and an ultramicroscopic dispersion, such as trypan blue. The placenta and fetal membranes in these experiments remained entirely unstained, whereas the cells of the liver, spleen, bone-marrow, and lungs were laden with the phagocytosed particles.

In another series of experiments Dr. Wislocki introduced solutions of different degrees of diffusibility into the peritoneal cavity of fetal cats and guinea-pigs. When phenolsulphonephthalein, an easily diffusible true solution, is so injected, it is absorbed by the fetal blood-stream and conveyed to the placenta, through which it slowly diffuses into the maternal circulation and is excreted by the maternal kidneys. It is also excreted by the fetal kidneys, being found in the fetal bladder in every instance in which sufficient urine could be collected to test for its presence. When trypan blue, a less diffusible colloidal dye, is injected into the fetal peritoneal cavity, it is absorbed, vitally stains the fetus, and is excreted by the fetal kidneys. It is not, however, transmitted through the placenta to the maternal tissues.

Mitochondria in the Placenta.

Inasmuch as the character and distribution of the mitochondria are thought by some to be an index of the metabolic activity of a cell, it is of interest to know the relative distribution of these structures in the maternal and fetal parts of the placenta. With this in mind, a survey has been made by Dr. Wislocki and Dr. J. A. Key of mature placentæ from a variety of mammals which were appropriately prepared for the demonstration of mitochondria. It was found that, while mitochondria are present in all of the fetal and maternal tissues of the placenta, they are particularly abundant in the cells of the epithelial membrane constituting the barrier between the two circulations. They are also abundant in the endothelium lining the maternal blood-channels and in the glands of the uterine mucosa. The functional activity of a given type of cell apparently is the determinative factor in the distribution of the mitochondria, rather than any inherent difference between the fetal and adult state. The placentæ studied included: (1) the pig, in which the chorion is merely apposed to the folds of the uterine mucosa; (2) the cat, in which a more intimate union results from the invasion of the mucosa by the chorion; (3) the guinea-pig, in which a still more intimate fusion of the chorion with the uterine wall occurs, including erosion of the maternal vessels and the disappearance of their endothelium, leaving a single layer of chorionic epithelium between the two blood-streams; and (4) the human, in which the conditions are much like those of the guinea-pig. In their final paper, these investigators have carefully described and illustrated the finer histology of these different types and the associated modifications in the distribution of mitochondria.

PATHOLOGY OF THE FETUS.

Several papers, based wholly or in part upon the pathological specimens and records in our collection, have appeared during the year.

Dr. J. P. Greenhill has published a description of the histological changes in the tissues of the fetus in an advanced case of missed abortion. Professor P. E. Lineback has reported the occurrence of polydactyly in a 22-mm. embryo, which apparently is the youngest case thus far known. Drs. E. A. Park and G. F. Powers, of the Department of Pediatrics of the Johns Hopkins University, have completed a study of congenital malformations of the head with coincident symmetrical malformations of the extremities. Although their conclusions are to be considered tentative, Park and Powers express the view that defects of this character originate in the germ-plasm itself, and they point out cases of oxycephaly and scapocephaly in which there is a known history of familial incidence. Their conclusion is in harmony with Dr. G. W. Corner's observations on the frequent occurrence of degenerative changes and abnormalities of growth in young pig embryos before the time of their implantation, mention of which was made in the last Year Book. Dr. Corner's work has now been published in its completed form. It is of considerable clinical significance that his observations make it probable that, to a large extent, we are to find the cause of pathological human embryos in primary germinal defects rather than in abnormalities of the implanation site.

Syphilis in the Fetus.

Of the normal-appearing specimens that come to this laboratory, a considerable number, we are aware, are probably syphilitic. We have, however, heretofore lacked any satisfactory method for the definite recognition of the presence of this disease in the fetus and have been entirely unable to determine the extent to which syphilis is responsible for intrauterine death. At one time it was thought that the Wassermann test might serve as an indicator, but the experience of Professor Williams, in the Johns Hopkins Hospital, has shown that a positive reaction is rarely obtained—so rarely, in fact, that the examination of the blood from the cord of the new-born has been discontinued as a routine procedure. In view of this, the successful experience of Dr. P. G. Shipley and his collaborators in the recognition of bone changes by the use of the X-ray is particularly welcome. Skeletal X-ray plates were made of 300 white fetuses ranging in age from the twenty-fourth week of intrauterine life to term. All of these fetuses, on the basis of the external form, had been classified in our collection as normal. Of 100 selected plates, 25 per cent showed distinct syphilitic involvement of the bones. The sites most often and most severely affected were the ends of the long bones of the extremities. No bones, however, were exempt; even the bodies of the vertebræ and the bones of the skull did not always escape. The shadow of the syphilitic fetal bone differs from that of the normal as a result of the irregularities in the calcification of the provisional cartilage and the consequent abnormal arrangement and distribution of osseous tissue. Experience may teach us that every syphilitic does not show these bone lesions, but in the use of the X-ray we evidently have a method which has the advantage of rapidity and ease of application and which will yield valuable diagnostic data and insure recognition of the presence of syphilis in a large number of cases that would otherwise escape detection.

Survey of Pathological Specimens.

In 1917 the late Professor Mall had begun the preparation of an analytical survey of all of the pathological specimens in the Carnegie Embryological Collection. In this undertaking he had obtained the cooperation of Professor Arthur W. Meyer, and at the time of Dr. Mall's death the plan of the study had been mapped out and the work advanced to a stage where it could be taken over by Dr. Meyer and carried through to a conclusion. Owing to the comprehensive character of the study, it has taken over three years for its completion and publication. The work has now been issued as Volume XII of the Contributions to Embryology and constitutes a reference book that promises to be of great service to this laboratory as well as to other workers concerned with the pathology of the antenatal period.

The monograph is divided into chapters which cover studies on different topics. The earlier chapters were written by Dr. Mall and deal with the origin of the collection, the storage, classification, and methods of study of the material, together with the protocols of all the pathological specimens among the first 1,200 accessions. These protocols have been entirely gone over by Dr. Meyer and in part rewritten. The succeeding chapters include a series of studies by Dr. Meyer, covering special features relating to the pathology of the embryo and the cause of abortion. Five of the chapters refer especially to the villi, the frequent occurrence of the hydatiform type of degeneration, and the significance of the Hofbauer cell, reference to which has been made in previous reports. Two chapters are devoted to intrauterine post-mortem changes in the fetus and to the problem of resorption of the conceptus. Other chapters review the structural changes in the fetus and placenta associated with syphilis, the correlation between the size of the chorion and the contained embryo in the normal and pathological specimen, and the probable non-occurrence of superfetation. The final chapter contains a general discussion of the frequency and cause of abortion. There is a chapter on localized anomalies, written by Dr. Mall, and a chapter on ovarian pregnancy, written jointly by the two authors.

Sex-Incidence.

Mention should be made of the study of sex-incidence in abortions by Dr. A. H. Schultz, which is embodied as one of the chapters in the monograph of Mall and Meyer, just referred to. This study is an extension of an earlier work on sex-ratio, an account of which was given in a previous report. Dr. Schultz points out that the primary or true sex-ratio, being conditioned upon sex-determination, must always remain more or less speculative. The secondary sex-ratio, that is, the proportion of males to every 100 females among the living-born, obviously would not be the same as the primary unless the number of males and the number of females that die *in utero* were exactly the same. This secondary sex-ratio has been estimated by Dr. Schultz, on the basis of numerous statistics gathered from the literature, to be 105.5. The tertiary, or adult, sex-ratio decreases with age, owing to the high rate of postnatal mortality among males. In order to compute the primary from the secondary sex-ratio, two factors are taken into account: the sex incidence among aborted fetuses and the relative frequency of abortions to full-term births. No data regarding sex incidence in abortions during the first three months of pregnancy are available, since sex-differentiation at this period is difficult or impossible. Deductions were drawn, however, from material from the third month to term. Dr. Schultz's more recent investigations, covering a larger number of specimens, tend to confirm his earlier findings, and also agree in the main with those of a number of other observers. From approximate averages he estimates that there are 28 abortions and still-births to every 100 living-born, and that the sex-ratio of these 128 fertilized ova is 108.74, as compared with his first estimate of 108.47. By careful studies on an ever-increasing number of specimens, and by the improved methods of sex recognition described by Spaulding, we may hope in time to reach a fairly satisfactory conclusion regarding this interesting question.

From 1899 to 1920, 183 Cæsarean sections were done in the obstetrical service of Professor J. Whitridge Williams at the Johns Hopkins Hospital. In a recent study of this experience, Dr. Williams found that in 99 operations, in which observations were made upon the ovaries, no corpus luteum was discoverable in one-third of the cases, while it was present in the other two-thirds, occurring in the right ovary 36 times and in the left 28 times. Where the corpus luteum was present in the right ovary 23 boys and 13 girls were noted, and where it was situated in the left ovary there were 16 boys and 12 girls; that is, the distribution was not correlated with the sex. Conclusive evidence is thus furnished of the fallacy of the old theory that boys are derived from one and girls from the other ovary.

COMPARATIVE STUDIES ON PRIMATE FETUSES.

During the past few years Dr. A. H. Schultz has been engaged in an anthropological study of fetal growth in whites and negroes. Recently, through the generous cooperation of other laboratories and museums, he has been able to make similar studies on a number of other primate fetuses. A list of this rare material follows:

No. of fetuses.	Species.	Source.
6	Guiana howling monkey......	W. Beebe, N. Y. Zool. Society.
1	Cebus monkey..............	Do.
1	.....do.....................	G. Miller, U. S. Nat. Museum, Washington.
3	Presbytis monkey...........	Do.
3	Nasalis monkey.............	Do.
1	Colobus monkey............	Do.
3	.....do.....................	H. Lang, Am. Mus. Nat. Hist., N. Y.
3	Baboon....................	W. Felix, Univ. of Zurich, Switzerland.
1	Gibbon.....................	Do.
6	.....do.....................	G. Miller, U. S. Nat. Museum, Washington.
5	Orang-utan.................	Do.
1	Chimpanzee................	G. S. Huntington, Columbia University.

Three papers by Dr. Schultz, based on the study of this material, are now in press. One of these concerns his observations on the proportions of three colobus fetuses, as compared with those of the human. He finds the trunk to be much longer and slenderer than that of the human fetus, the chest narrower, and the position of the nipples and umbilicus relatively higher. The extremities are relatively shorter and the hands and feet more slender. The head is smaller, but the face, in proportion to the brain part of the head, is larger than in the human fetus. In general, ossification in these colobus fetuses corresponds very closely to that of human fetuses of corresponding stages of development. In both colobus and man the head grows more slowly than the trunk, and the lower extremities faster than the upper ones, growth being more rapid in the distal than in the proximal parts. In both, also, the relative length of the cervical and thoracic portions of the spine decreases during growth, while that of the lumbar portion increases. In the colobus the thumb is rudimentary, but still retains a short metacarpus and one phalanx. The degree of reduction of the thumb and the age at which it disappears completely from the surface of the hand vary in different species. A fact of special interest is that in all of the colobus fetuses several sinus hairs were present on the inner side of the forearm, proximal to the carpus. These were more conspicuous and of relatively greater length in the youngest fetus than in the two older ones. In the adult colobus no trace of these hairs can be seen. They correspond to the vibrissæ found in all prosimiæ and have heretofore been believed to be missing in all monkeys. Their discovery in the fetus, therefore, in which they develop apparently only to disappear later, furnishes further proof of a close relationship between lemurs and monkeys.

In another paper Dr. Schultz gives the results of a metric and osteological study of fetal and adult specimens of the Guiana howling monkey, which, besides placing this new and rare material on record, throws additional light on the laws of growth in primates. On comparing the two alouatta fetuses with human fetuses of corresponding stages of development, it is found that they differ in the following points: In the alouatta the trunk is more slender, the shoulders, nipples, and umbilicus are situated higher, the upper extremities are relatively longer, the hand and foot very much longer, and the thumb and great toe shorter; the brain part of the head is smaller, especially in height, the nose is higher, and the ear larger. During development the forearm of the alouatta grows faster than either the upper arm or the hand; likewise the lower leg has a greater rate of growth than the thigh or foot. As a whole, the lower extremity grows more rapidly than the upper one. The relative length of the fingers and toes remains unchanged during development. The relative size of the brain part of the head decreases, whereas, that of the face part remains constant during growth. As regards the different portions of the spinal column, the relative length of the thoracic region decreases, while that of the lumbar, sacral, and caudal regions increases. Of special interest in the skeleton of the alouatta is the forking of the manubrium sterni into two diverging processes, due to the enormous development of the hyoid, a condition which is pronounced even in the fetus. The foramen zygomatico-temporale, a remnant of the former complete communication between orbital and temporal fossæ, is of considerable size in the fetal skull.

The rare circumstance that the two alouatta fetuses were single-ovum twins afforded an opportunity to test the frequently asserted "identity" in such twins. It was found that on an average a given measurement differed in the two fetuses 4.81 per cent.

In a third paper Dr. Schultz describes the occurrence of a sternal gland in the fetal and adult male orang-utan. In the middle of the chest, at the level of the nipples, is a pit-like depression in the skin, which is the outlet for numerous unusually large sebaceous glands conglobated beneath. This sternal gland occurs in but a small percentage of female orang-utans and is relatively larger and more conspicuous in male fetuses than in the old animals. The pit may reach a diameter of 2.5 mm. and a depth of even 3.5 mm. At times it is surrounded by a low circular wall or, especially in later life, by a dark brown pigmented zone. This gland in primates seems to be restricted to orang-utan; an analogous gland, however, has been observed in some chiroptera and marsupials.

DEPARTMENT OF GENETICS.*

C. B. Davenport, Director.

GENERAL STATEMENT.

The organization of the Department of Genetics consolidates and unifies the work of eugenics and experimental evolution and places an institution for the study of human heredity and reproduction in the same organization with one for the experimental breeding of other mammals, animals, and plants. It is believed that the combination will be peculiarly advantageous for fruitful research; a profound biological investigation of mankind and his biotypes, their variations of form and behavior and their genetical significance, has not hitherto been carried out.

Of the work of this Department during the past year, may first be mentioned the researches that are demonstrating the close relationship between variations in chromosome number and specific variations in the form and other qualities of the body. The work on *Datura stramonium* is offering remarkable explanations of the complexities of de Vriesian mutation, a form of mutation of possibly not less general significance than Mendelian mutation. While research has not yet put "the mind into the chromosome," it seems not improbable that some mental "sports" in man, that deviate widely from the typical condition, may some day be found due to such abnormalities in the chromosome complex as are now known to characterize striking forms of *Datura*. Attention is called to the discovery (page 132) that the hybrids between two forms of domestic mice (one active and the other slow) are on the average more active, sturdy, and intelligent than *either* parental race. This is a quantitative result based on painstaking measurement of nearly 300 individuals.

Another matter of great theoretical as well as practical importance is the demonstration that in mice there are hereditary physiological factors that render certain strains and their hybrid descendants susceptible to the growth of tumors. In the absence of these factors inoculated tumors will not grow. Moreover, the genetic nature of these factors of susceptibility varies in different strains. Hitherto our strains of mice have shown a complex genetic constitution, in that probably four factors were required to determine susceptibility. During the current year it has been demonstrated that in one strain of mice the combination of two factors, merely, is required for susceptibility. In this strain the Mendelian nature of inheritance of susceptibility to inoculated cancer is so simple as to be easily demonstrated to the most skeptical. The discovery of the hereditary factors in inoculable cancers constitutes obviously one of the most important advances in cancer research.

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*Situated at Cold Spring Harbor, Long Island, New York.

Other matters of interest are cited below.

(1) The demonstration that the sex-determiner apparently does not lie in similar chromosomes in closely related species of *Drosophila.* This opens up new and interesting difficulties in the study of the homology of the chromosomes.

(2) Evidence that male and female embryos of pigeons are different in their metabolism.

(3) Success in controlling the sex-ratio in certain aquatic entomostraca by varying the number of mothers in a unit of water.

(4) A study of mammalian spermatozoa, showing that, unlike those of some insects, they do not fall into two types in respect to size.

(5) The demonstration of the possibility, in one strain of the sex-intergrade *Daphnia,* of changing the degree of intergradeness by selection.

(6) The observation that a form of parasitism in *Daphnia* induces sex-intergradism.

(7) Age of mice greatly influences their susceptibility toward inoculated tumors; the reactions of a non-susceptible race to tumors is to a remarkable degree related to the activity of the gonad.

(8) Evidence has been secured that capacity for successful transplantation of tissue (spleen) from one individual to another of the same race depends upon the genetic uniformity of the race.

(9) Evidence that in white cats the gametes carry lethal factors, which operate even in the simplex condition.

(10) The inauguration of a method of testing quantitatively the instincts and intelligence of dogs.

(11) The clear evidence that timidity has an inherited basis in dogs.

(12) A demonstration that etherized non-waltzing mice fall into the same three groups of dextral, sinistral, and neutral whirlers that are found in Japanese waltzing mice.

(13) The conclusion that in mating (of flies) where a close approximation to a 1: 1 Mendelian ratio is expected, selection can isolate lines in which the zygotic ratio departs widely in the desired direction from the expected.

(14) Evidence of non-disjunction in the fourth chromosome of *Drosophila.*

(15) A confirmation by statistical analysis of Schuster and Elderton's conclusion as to the degree of inheritance of scholastic ability between fathers and sons.

(16) Clear statistical evidence of the existence of human cancerous families.

(17) The completion of a first quantitative study of inheritance of musical ability, bringing evidence of its Mendelian behavior.

(18) The development of formulas for calculating ancestral inheritance.

(19) The publication, in cooperation with the Army, of the results of anthropometric measurements of recruits and veterans; with reference to habitat, occupation, race, and associated diseases.

(20) Evidence that abnormalities in development of pigeon embryos are often due to endocrine disfunctioning of the mothers.

(21) The elaboration of tables for predicting probable future egg-production in the fowl from its fecundity at any time.

(22) Evidence that alcohol tends to reduce the average size of litters and the number of litters. But in later generations from alcoholized rats the normal number of litters per rat may reappear, and may even be exceeded, probably due to selective elimination by alcohol of the weaker strains.

(23) Alcoholized rats grow more slowly than the controls; but *their* offspring grow more rapidly than the offspring of the controls.

(24) Proof that (in swine at least) the migration of ova from one ovary through the body-cavity to the opposite tube is rare. On the other hand, there is a migration of ova within the uterus which tends to secure a uniform distribution of embryos and to prevent crowding.

DETAILED REPORTS ON INVESTIGATIONS IN PROGRESS.

INTERCHROMOSOMAL MUTATION.

The modern work on mutation dates from the publication of De Vries's classic monograph, "Die Mutationtheorie," 1901–03. This study was based on the evening primrose (*Oenothera lamarckiana*). When De Vries gave the opening address at the Station for Experimental Evolution in 1904, he expressed the hope and expectation that his *Oenothera* work would be continued by this department (third Year Book of the Carnegie Institution of Washington, pp. 48, 49). We tried for some years to do this through the work of Dr. G. H. Shull and Miss Anne M. Lutz. Many others took up the work and, with the departure of Dr. Shull, it was for a time abandoned here. With the coming of Dr. A. F. Blakeslee the search for genetically simpler mutating plant material has been continued, and has now been rewarded by finding it in *Datura stramonium*. This species has only 12 pairs of chromosomes, and its habit of growth is rather definite. In ease of guarding the pollination it leaves little to be desired. The outstanding feature of the species is that it, like *Oenothera*, is undergoing a variation in its chromosome-complex; and with every variation in its chromosome-complex goes a special somatic form. This department is now fully launched on a program of work with this valuable form, and we trust that with appropriate support the analysis of De Vriesian mutation can be carried beyond anything hitherto accomplished.

This work requires the cooperation of many sorts of workers: (1) The analyst who makes the matings and coordinates the results; this part of the work is in the hands of Dr. Blakeslee. (2) The cytologist, who studies the chromosomal complex (number and form) associated with each somatic variant and the distribution of chromosomes in hybrids and their progeny. (3) The student of pollen and pollen-tube growth, to test on the one hand pollen sterility and on the other that of differential growth, and, hence, differential fertilization. (4) The analyst of the elements of somatic form. (5) The chemist, who should study the chemical differences associated with differences in form.

General Account of the Datura Mutants.

A preliminary report on the jimson weed (*Datura*) was made by Blakeslee, Belling, and Farnham in Science, October 22, 1920, under the title "Chromosomal duplication and Mendelian phenomena in *Datura* mutants." In this paper it is pointed out that just as there are 12 chromosomes (A, B . . . . K, L) in the gametes so there are 12 mutants from the normal form, in each of which 1 extra chromosome is present; and evidence is presented that in each of the 12 mutants the extra chromosome is a different one; i. e., in one there is an extra A, in another an extra B, and so on. Of the pollen grains of these mutants, half have 12 chromosomes and half have 13; and evidently the same is the case in the egg cells; but apparently the pollen with 13 nuclei is non-functional. The authors announce also the discovery of triplets in place of pairs of every kind of chromosome; and also a case of quadrupled (tetraploid) chromosomes.

Dr. Blakeslee reports that the field records of the present season are not yet complete, but the data so far obtained warrant a classification of the known mutant types according to their chromosomal constitution as shown in table 1 and diagrams (fig. 1).

Dr. Blakeslee proceeds:

"The classification adopted was suggested in a recent paper in the American Naturalist.

"Of the unbalanced types, the first mutants discovered were simple trisomic diploids due to an extra chromosome in a single set. Last year we had gained evidence which indicated that Poinsettia is the mutant that has the extra chromosome in the set carrying the factors for purple and white flower color. This evidence, from the peculiar ratios obtained when these Mendelian characters are transmitted, has been increased by further data acquired this year. By similar breeding evidence it is rendered highly probable that Cocklebur is the mutant with an extra chromosome in the set carrying factors for spininess of capsules.

"Triploids have been secured by crossing tetraploids with normals.

"The double trisomic diploids have been secured in the offspring from triploids. Since in the latter each set has 3 chromosomes, the gametes will receive from each set either 1 or 2 chromosomes at reduction division. In consequence, the types of gametes produced by triploids by the theory of chance should correspond to a binomial expansion and we should have in different offspring all possible combinations of sets with 2 and with 3 chromosomes. Apparently differential viability and other factors prevent a close approximation to the laws of chance and we are getting in our triploid offspring many diploids, the common simple trisomic mutants and a considera-

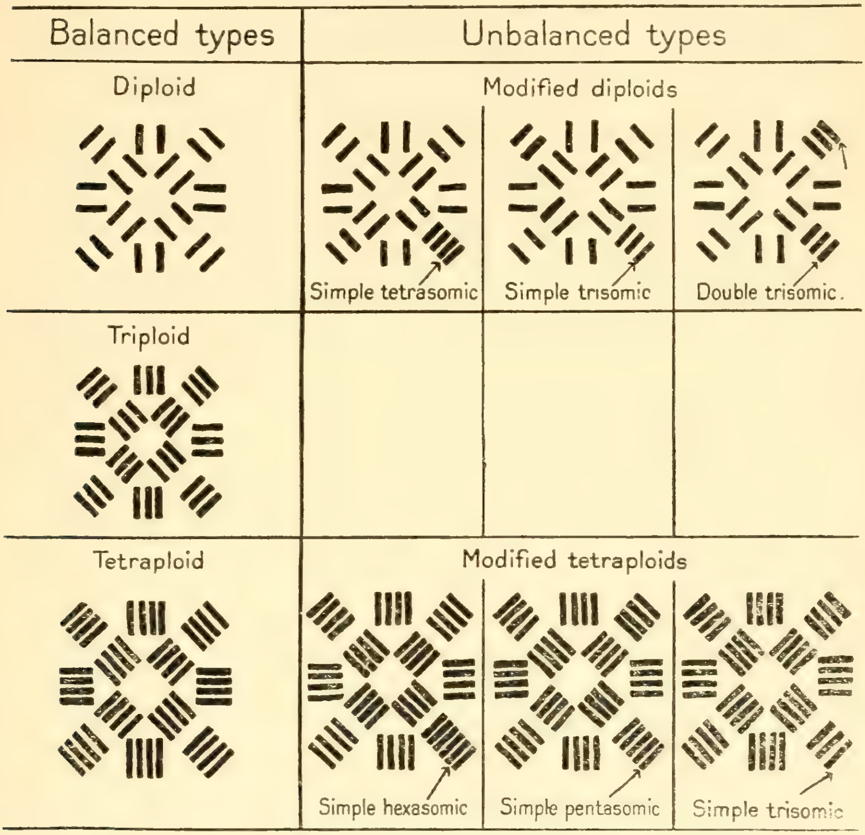

Balanced types
Unbalanced types
Diploid
Modified diploids
Simple tetrasomic
Simple trisomic
Double trisomic.
Triploid
Tetraploid
Modified tetraploids
Simple hexasomic
Simple pentasomic
Simple trisomic

Fig. 1.

Table 1.—*Chromosomal types of mutants in the jimson weed* (*Datura stramonium*).

The somatic number of chromosomes is given in parentheses after each type.

Balanced Types (12n): Diploids (Normal) (24); Triploids (36); Tetraploids (48).
Unbalanced Types (12n+x):
  Modified diploids (24+x).
    A. Simple trisomic (24+x): 1, Globe; 2, Poinsettia; 2a, P. var. Wiry; 3, Cocklebur; 4, Ilex; 5, Mutilated; 6, Sugar-loaf; 7, Rolled; 8, Reduced; 9, Buckling; 10, Glossy; 11, Microcarpic; 12, Spinach.
    B. Simple tetrasomic (24+2, the 2 extras in the same set): 1, Round-leaf Globe.
    C. Double trisomic (24+1+1, one extra in each of 2 different sets): 1, Ilex-Buckling (?) and a number of other double mutants not yet analyzed by breeding tests.
  Modified tetraploids (48+x).
    A. Simple pentasomic (48+1): 1, Globe; 2, Poinsettia; 3, Cocklebur; 4, Ilex; 5, Rolled; 6, Reduced; 7, Glossy; 8, Microcarpic.
    B. Simple hexasomic (48+2, the 2 extras in the same set): 1, Globe.
    C. Simple trisomic (48–1, a single deficiency in one set).

ble number of double trisomic mutants with 2 sets each having an extra chromosome.

"This year we are finding chromosomal mutants in considerable numbers among our tetraploid pedigrees and before the season is over hope to identify a large majority of the simple pentasomic tetraploids corresponding to the simple trisomic diploids earlier discovered. Judging from appearances, we doubtless have double pentasomic forms in our pedigrees, but their classification must wait for cytological confirmation.

"A single case of a deficiency in chromosome number associated with semisterility of pollen has been found in a small trial pedigree from the cross triploid×tetraploid. Probably a considerable number of simple and double deficiencies may be expected from the sowing of a larger number of seed of this cross, which waits an opportunity of planting.

"The interest in the daturas does not lie chiefly in an accumulation of chromosomal types. The value of the work will lie, it is believed, rather in a possible closer insight into the nature of the chromosomes and processes of inheritance. The unbalanced mutants give us an opportunity of analyzing the contribution of each chromosome to the final structure and physiology of the plant.

"The four different Globe mutants will best illustrate the effect of the unbalanced condition. The simple tetrasomic Globe is a diploid, unbalanced by 2 extra chromosomes in the Globe set. The 2 extra chromosomes are more or less antagonistic to 11 sets with 2 members each, giving an unbalance of 2 to 22. In comparison with the simple trisomic Globes where the unbalance is 1 to 22, all the Globe characters in the tetrasomic Globe are increased in expression. The simple pentasomic Globe tetraploid has an unbalance of only 1 to 44 and, as one would expect, the Globe characters are less distinct than in the simple trisomic Globes with an unbalance of 1 to 22. With this relation in mind, simple hexasomic Globes were sought for in which the unbalance should be 2 to 44 or 1 to 22, the same unbalance found in trisomic diploid Globes. They were identified in offspring of pentasomic Globes and their classification confirmed by chromosomal counts. Approximately half the pollen grains of simple trisomic Globes have an extra chromosome and their gametophytes therefore are unbalanced by 1 to 11. In consequence, very few male gametes are effective in fertilization, the trisomic character being transmitted to only about 2 per cent of the offspring. In the gametophytes of pentasomic Globe tetraploids the unbalance is less (1 to 22), so apparently we find that pentasomic Globes transmit the extra chromosome through the pollen to a much higher percentage of their offspring (about 15 per cent in this year's planting).

"The unbalanced condition gives us an opportunity, never before realized, of analyzing the influence of individual chromosomes without waiting for the appearance of gene mutations. Heretofore, the number of factors determined in the chromosomes has been dependent upon the number of mutated genes available for crossing with the normal type. In the jimsons, however, we may study the sum total of all the factors in individual chromosomes by the unbalancing effect upon the structure and physiology of the plant when a single specific chromosomal set has 1 or 2 extra chromosomes."

While the advance of knowledge of influence of single entire chromosomes on the developing plant-body has been great during the past 12 months, yet the number of new problems in this field has increased in the same ratio. The need for additional workers with this extraordinarily valuable material is great. For the most part, the additional workers will find it advantageous to work at the Station for Experimental Evolution; but some of them may be able to carry on parts of the work elsewhere.

The Cytology of Datura Mutants.

Especially valuable has been the assistance in this work given by Mr. John Belling. He has perfected a new method for the examination of chromosomes in pollen-mother cells which avoids the tedious method of cutting paraffine sections, and apparently renders possible more accurate results than have hitherto been possible in counting chromosomes. This method consists of the rapid fixing and staining of the pollen-mother cells (freshly squeezed from the anthers) with iron-aceto-carmine. These cells are caused to separate and then to flatten out, by the aid of gentle pressure, after they have been for 24 hours in the reagent. This method has proved eminently suitable for the purpose of counting and estimating the size of the chromosomes in the second metaphases of chromosomal division. This method reveals also the grouping of homologous chromosomes in the late prophases. Mr. Belling finds, indeed, that in *Datura* the total number and assortment of chromosomes in the mother plant are ascertained with greater certainty by counting both second metaphase plates in the same cell than by counting the somatic chromosomes in the body tissue, say the root-tip. By combining size estimations in the late first prophase and in the second metaphase it is possible to recognize the particular chromosome or chromosomes whose excess number characterizes the various mutants.

This specificity of the different chromosomes of *Datura* is a matter of great importance for the analysis of the unbalanced chromosome types. Though these 12 chromosomes look alike to the casual observer, prolonged study shows that they fall into six grades of size: 1 largest, 4 large, 3 large medium, 2 small medium, 1 small, and 1 smallest. In triploid *Daturas* the 36 chromosomes are in 12 groups of 3 each. In tetraploid *Daturas* the 48 chromosomes are in 12 groups of 4 each, each group forming a figure 8. In triploid and tetraploid all of the 3 or 4 chromosomes in each group are of the same size. In simple trisomic plants there are 11 ordinary paired chromosomes and 1 trivalent, like the trivalents of the triploid plant. In the mutant Globe all three chromosomes are small. In the mutant Mutilated all three are large.

In triploid plants, at the early anaphase of the first division, 2 chromosomes of each trivalent go toward 1 plate and 1 chromosome toward the other. In the normal diploid *Datura,* non-disjunction occasionally gives rise to an assortment of 11:13 in the second metaphase stage. This non-disjunction was seen once in 100 cells observed. In the higher "balanced types" of excess chromosomes, the metaphase plates tend to have an equal number, but inequality is not uncommon, and the rarer the greater the inequality. It also appears that homologous chromosomes are attracted, even if each group has an abnormal number, like 3 or 4.

When triploid is crossed by normal diploid the offspring are peculiar in respect to assortment in the metaphase of pollen-mother cell. Thus in 24 plants the chromosomes separated as 12:12; in 31 plants as 12 : 13; in 10 plants as 12 : 14 or 13 : 13. Since one might expect the chromosomes to separate as 15 : 15, it is clear that many chromosomes must have been eliminated somewhere in the process of hybridization. Such eliminated chromosomes are found in the pollen-mother cells and form micronuclei, which come to lie in microcytes. Of the few progeny of the numerous crosses of tetraploid by normal where the assortment 18 : 18 is to be expected, in five cases it was 12 : 12; once 12 : 13, and in three cases it ranged from 12 : 24 to 18 : 18. Here again chromosomes must have become lost. There is a strong tendency to restore the normal chromosome number. The progeny of triploid by tetraploid mutants were few. Three plants assorted 24 : 24 or 23 : 25; one plant gave 23 : 24. The expected 21 : 21 was not found. Here again internal adjusting factors are present.

An attempt has been made to arrange mutants in order of size of the trisomic group upon which each mutant depends. The result is tentative and is as follows: Mutilated (largest), Glossy, Buckling, Cocklebur, Sugarloaf, Spinach, Microcarpic, Ilex, Wiry, Poinsettia, Globe, Reduced. Rolled and Elongated have not yet been included.

A beginning has been made in the determination, in trisomic mutants, of the average numbers of microcytes with eliminated chromosomes; and also the numbers of double-sized pollen-grains with a double number of chromosomes. Also, the difference in nature of the extra chromosome in the simple trisomics is being correlated with the range of variation in size of the mature pollen-grains, with normal diploids, triploids, or tetraploids; the volume of the pollen-mother cells, or of the pollen-grains, has been shown to be proportional to the number of chromosomes; but it has not yet been shown that this rule holds when only one chromosome is doubled. Of the 12 possible pentasomic tetraploids, only a few have been as yet studied cytologically. Of the 12 possible simple tetrasomic diploids only one has as yet been identified, and only 1 of the possible 12 hexasomic tetraploids. The simple trisomic tetraploid is of especial scientific interest, because of the effect of the loss of one chromosome, which causes the abortion of half of the pollen.

It may be added that Mr. Belling's analysis, given above, of the cytological conditions accompanying *Datura* hybrids has been of the greatest possible assistance in the interpretation of the originally baffling phenomenon of mutation in *Datura*.

COOPERATIVE WORK ON DATURA MUTANTS.

The *Datura* work is of such great theoretical importance that it deserves all the cooperation that can be secured for it. We have been very fortunate in getting such assistance, largely by volunteers who have offered their cooperation without pay. Among these collaborating are the following:

Dr. E. W. Sinnott, of Connecticut Agricultural College, is studying the differences in gross morphology and in histology between chromosomal types.

Dr. John W. Buchholz, of the University of Arkansas, has perfected a rapid method of isolating pollen-tubes and of studying their growth without the aid of paraffine sections. He is investigating the behavior of pollen and egg cells in the different chromosomal types which may throw light upon incompatibilities between races and species.

Dr. J. Arthur Harris, of this Department, is investigating the influence of the extra chromosomes upon the sap concentration by means of determinations of freezing-point and of electrical conductivity.

Dr. C. Stuart Gager, Director of the Botanic Garden, Brooklyn Institute of Arts and Sciences, is investigating the possible effect of radium emanations upon gene and chromosomal mutations.

Mr. J. L. Cartledge, of the University of Pennsylvania, worked at Cold Spring Harbor during the past summer upon the question of pollen sterility.

It is hoped that further cooperation can be secured in the coming months. Especially profitable is the arrangement by which professors, freed of other duties, can spend their vacations at so agreeable a spot as Cold Spring Harbor at a time when the *Daturas* are actively growing and flowering.

NON-DISJUNCTION OF THE FOURTH CHROMOSOME OF DROSOPHILA.

In the course of a selection experiment with *Drosophila melanogaster* peculiar behavior of the characters "normal eye" (N) and "eyeless" (n) has been observed and studied by Dr. Little. Although no cytological supporting evidence has been obtained, the genetic results are best explained on the supposition that triploidy and tetraploidy of the fourth chromosome have taken place. Certain additional hypotheses also appear to be necessary, as follows: The reduction during gametogenesis of Nnn flies is usually (although not exclusively) of the Nn–n type; that of the NnNn type is random. The somatic appearance of the Nnn, NnNn, and Nnnn flies is sometimes normal and sometimes eyeless. The proportion of these forms which appear in any given mating seems to be influenced by modifying factors.

This suggests that the somatic appearance of these types as well as the nature of the reduction division may be different in different lines. As the whole matter involves detailed analysis of the genetics of the case on the basis of the numerous other genes, already known and daily being added to in *Drosophila*, no effort will be made to carry on the experiment further at this station, since it arose as a side issue in an entirely different line of work. The results obtained are almost ready for publication.

CAUSES OF STERILITY; ABORTION OF POLLEN GRAINS.

In the study of *Datura* it is highly important to recognize that many mutants produce pollen of which nearly half is sterile. This sterility is probably due to an abnormal number of chromosomes in the pollen. It is especially apt to occur in hybrids between mutants. Mr. John Belling has spent some time during the past year on this topic. He finds that, in the Orchidaceæ, which he was able to study through the courtesy of the Missouri Botanical Garden, the hybrid pollen frequently is normally formed. The pollen-mother cell divides regularly into 4 cells, forming tetrads, just like those of a wild species. Accordingly, microcytes were very rare. In the genus *Papheopedilum*, on the other hand, where each tetrad divides into 4 pollen-grains, the species hybrids show a large percentage of aborted pollen. The following types of abortion of pollen-grains have been found:

(1) Chance abortion of a fraction of the grains, altering slightly or greatly with environmental changes; and probably due to the somatic constitution of the plant, and not to constitutional differences among the pollen-grains themselves. This was found in some *Canna* clones; and, superposed on types (2) or (4), in *Stizolobium* and *Rhododendron*.

(2) Abortion of a Mendelian fraction of the pollen-grains due to the absence of vital genes through a mutation or as a result of crossing. This was found in *Stizolobium* and apparently in *Rhododendron*, sometimes with type (1) superposed.

(3) Abortion similar to type (1), but due to the presence of an extra chromosome. Found in some of the simple trisomic daturas; and more accentuated in the double trisomics and in the simple tetrasomic.

(4) Abortion, like type (2), but due to the absence of one chromosome of a set. Found in the *Datura* with 47 chromosomes assorting 23 to 24. Apparently all the 23 chromosome pollen-grains abort. Since some tetraploids produce much 23-chromosome pollen, the same cause may be at work in them. Possibly this is also the cause of abortion of half the grains in some partially triploid *Canna* clones with one or more missing chromosomes.

(5) Abortion due apparently to frequent non-disjunction, and varying with environment from 38 to 100 per cent. This was found in one nearly sterile *Canna* clone.

(6) Abortion probably due to the absence of proper pairing among the 18 chromosomes, so that the assortment 9 : 9 is absent or rare. This was found in one sterile *Canna* clone.

Mendelian abortion among the pollen-grains is well illustrated in a certain presumably hybrid *Rhododendron*. These plants are known to have their mature pollen-grains firmly adherent in sets of four. In most clones examined, and in one named hybrid kindly given by the Arnold Arboretum, there were varying numbers of empty grains, but the abortion showed no relation to the arrangement in fours. In one clone, however, which differs from the others in its flowers, no tetrad was found in any flower in which two of the grains were not empty of cytoplasm.

COMPARATIVE STUDY OF THE CHROMOSOME GROUPS IN DIPTERA.

This study is in charge of Dr. C. W. Metz, who has had associated with him Dr. E. G. Anderson and Mrs. Rebecca C. Lancefield and has been assisted by Miss Mildred S. Moses, and, temporarily, by Mr. S. H. Emerson. The work undertaken comprises the comparative study of the genetical content of the germ-plasms of *Drosophila melanogaster*, *D. willistoni*, and *D. virilis;* the survey of the Diptera for the most favorable genetical material; and the initiation of work on a fly (rather distantly related to *Drosophila*), *Leria pectinata*.

DROSOPHILA WILLISTONI.

The combined genetical and cytological study of *Drosophila willistoni*, in which Dr. Metz and Mrs. Lancefield cooperated, has yielded surprising results. Dr. Metz states:

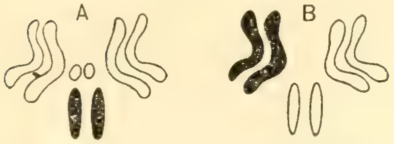
"*Drosophila willistoni* resembles *D. melanogaster* sufficiently to suggest that it is fairly closely related to this species, and the normal chromosome groups of the two are superficially almost alike. These are shown in figure 2, A and B. Owing to these resemblances it was supposed, at first, that the pairs of chromosomes in one species corresponded respectively to the similar pairs in the other (aside from the minute pair which seems to be absent in *willistoni*). But a study of 'non-disjunction' flies (flies with an extra sex chromosome) has shown that the sex chromosomes in the two species do not correspond. In *D. melanogaster* the rod-like pair is the sex-chromosome pair (Stevens, Bridges), whereas in *D. willistoni* we have found that one of the large V-shaped pairs is the sex-chromosome pair. This relationship is indicated in figures A and B, where the sex chromosomes are shown in solid black. The results are in press.

"Comparing the chromosomes of *melanogaster* and *willistoni* (fig. 2, A and B) it might be assumed that the corresponding pairs are essentially similar in their genetic make-up. In this case it must be assumed that the sex-differentiator (gene?) has been transferred from the rod-like pair (*melanogaster*) to one of the large V-shaped pairs (*willistoni*) or vice versa. If this is the case, then it might be expected that the sex-linked group of mutant characters in *willistoni* would correspond to one of the non-sex-linked groups in *melanogaster*, providing it resembled any group in this species.

"On the other hand, it might be imagined that the rod-like sex chromosome of *melanogaster* is represented by one arm of the V-shaped sex chromosome of *willistoni* and that the remainder of the V is not present in *melanogaster* or is included in one of its autosomes. In this case the sex-linked mutant characters in *willistoni* might correspond to the sex-linked ones in *melanogaster* plus an additional series.

"Other hypotheses are possible, among them the hypothesis of a radical chromosomal reorganization such that the chromosomal resemblances in the two species are purely incidental. It is hoped that the breeding work will give a clue to the correct explanation. Up to the present there is little indication of resemblance between the sex-linked group of characters in *willistoni* and any of the groups in *melanogaster*, so it will be necessary to secure many more mutants before this feature can be cleared up."

The conclusion that can be drawn from the foregoing data is that the cytological resemblance of chromosome groups may not safely be taken as a basis for conclusions concerning genetical relationships. It follows, also, that the tracing of chromosome evolution in the genus *Drosophila* will probably be found more difficult than was at one time hoped.



D. melanogaster ♀ D. willistoni ♀.

Fig. 2.—Diagrams of chromosome-complex. Sex chromosomes are shown in solid black.

The breeding experiments with *Drosophila willistoni* (carried on largely by Mrs. Lancefield) have included the analysis of 27 sex-linked characters and a smaller number of non-sex-linked characters The data on the sex-linked characters have been prepared for publication. In addition to the special points mentioned above, they indicate that the phenomena of crossing over in *willistoni* are similar in general to those in *melanogaster*. The genes for the 27 characters fall into a linear series, based on cross-over percentages, giving a "map" approximately 86 units long.

LERIA PECTINATA.

Work with *Leria pectinata* has been started by Dr. Anderson and the species has proved favorable for study. Isolations have been made of new types appearing either as mutations or as segregates from heterozygous flies found in the pigeon-houses. In a few cases the "off-type" flies have been collected or reared from collected larvæ. Several mutant races have been established or are being isolated. Some of these are of little value, because of low viability or great variability of the characters. The present need is for more characters that are sufficiently simple and clear-cut to be used as tools in the analysis of the more complex and less clearly expressed ones. The main objective of the present work is to accumulate as many of such as possible and to standardize cultural conditions.

EXPERIMENTAL MODIFICATION OF THE GERM-PLASM.

The Treatment of Mice with X-Rays Before Mating.

Dr. C. C. Little, in collaboration with Dr. Halsey T. Bagg, research fellow in biology of the Huntington Fund for Cancer Research, has been studying the effects of exposing mice to very small doses of X-rays. The experiment was begun in the autumn of 1920. A closely inbred strain of colored mice was used and the treatments were made before mating. Five consecutive daily treatments were given in doses that varied from 12 seconds to 360 seconds in exposure time. A 2.5-inch spark-gap was used, 10 milliamperes, and 12-inch distance. 129 mice were X-rayed. Several of the mice treated with the smaller doses mated and produced apparently normal young in the first generation. These were again inbred, and two young mice were found with apparently very abnormal eye conditions. These animals were found in the first and second litters of a single F_1 female. The developmental condition of the eye is apparently an index of disturbance in mammalian development in general, and the presence of these eye disturbances, occurring in a strain of animals which otherwise rarely show such malformations, is an interesting observation in itself; it is strongly suggestive of the possibility of altering the genetic constitution of these animals in still further ways. Recently some of the apparently normal F_1 animals were autopsied, and certain of the skulls have shown a peculiarly abnormally rounded dorsal convexity, associated with a slight asymmetry of the entire skull. Detailed histological study of these abnormal structures is being made at the time of writing. Further experiments are planned for the treatment of successive generations of mice with small doses of X-rays. The treatments were made by Dr. Bagg at the Memorial Hospital, New York City, while the actual breeding experiments and the detailed care of the animals were carried on at Cold Spring Harbor.

Modifiability of the Germ-Plasm by Alcohol.

Under this heading, or a similar one, there has been given in the Year Book since 1914, an account of an experiment on the effect upon the descendants of alcoholization of the ascendants. The account of the results obtained this year are accordingly placed here again. Meanwhile, it must be admitted that a large part of the clear results obtained are probably due to a selective elimination of certain genotypes through a direct physiological effect of alcoholization upon the mother, although it is still probable that some modification of germinal material has taken place. Dr. MacDowell reports:

"*Behavior in multiple-choice apparatus:* In the Year Book, 1920, pages 118–122, appeared a description of the operation of this apparatus. The summarization of the data from the children of treated rats can now be reported. The general features of the curves of correct and wrong choices for this generation are very like those formerly presented for the generation of the grandparents.

"The data for the offspring of treated rats (81 tests and 80 controls) came from two series of experiments: a first series in which the parents were given relatively light doses of alcohol, and a second series in which the parents were given alcohol fumes each day until the state of complete stupor was produced. All interpretation is dependent upon the significance attached to the performance in the preliminary trials, which differed from the regular trials in that the rats were fed in the first compartment chosen by them in those trials. Is the difference between the tests and controls (manifest in the preliminary trials) constant through the training or is it modified by the training? When the controls were grouped according to their preliminary performance, the averages for the successive sets of 20 trials (2 days) showed very slight relationship to the preliminary records. When the tests are similarly grouped, their preliminary performance is so closely related to the subsequent trials that a good prediction of the later behavior can be made from the preliminary performance. The statistical study of this point shows that the preliminary performance of the controls is very slightly correlated with the average of each successive set of 20 trials, whereas comparable correlation coefficients for the tests are high. This study has revealed the most striking difference between the tests and controls that has been brought out by the multiple-choice apparatus. The reactions of the controls are almost entirely changed by the introduction of the training, while the reactions of the tests remain about the same as in the preliminary trials. This may be a difference in responsiveness to changes in the situation, the tests being less responsive to the changed circumstances than the controls. In view of the above, the least objectionable way of making the final comparisons of averages of tests and controls appears to be to eliminate all rats with preliminary records beyond certain limits (for instance, with more than 12 or less than 3 correct trials in the preliminary trials). This removes the difference in the averages for the preliminary trials. When this is done the graphs of the averages show the tests making fewer correct choices in each set of 20 trials after the first one. As the differences increase they become statistically significant.

"*Behavior in maze:* In the Year Book for 1920 the maze-behavior of the children and grandchildren of alcoholized rats was reported. The children, at that time, subject to correction, have been rechecked through the cooperation of Dr. Harris. The great mass of the statistical work herein reported, however, has been carried out in this department with the assistance of Mr. L. H. Snyder and Miss Vicari.

"The behavior data for the original treated rats and treated rats from treated parents have been tabulated and the summaries are ready for publication. 71 original treated rats (with 67 controls) and 8 treated rats from treated parents (with 20 controls) were given their trials in the maze each day before the alcohol treatment.

"In general, the tests took more time than the controls; the offspring of treated rats show less difference than any other generation. The other three generations (1, treated; 2, treated from treated parents; and 3, untreated from untreated parents and treated grandparents) show more or less the same general differences between the tests and controls. In other words, this difference is neither dependent upon the presence of alcohol itself, nor is it intensified by the treatment of two successive generations. This result is similar to that given by the size of the litters produced in the different generations."

THE SIGNIFICANCE AND CONTROL OF SEX.

The Fundamental Nature of Sex.

The phenomenon of two sexes runs through the world of organisms with a constancy that is hardly found in any other phenomenon, yet with sporadic apparent exceptions which have attracted the attention of biologists from an early time. A phenomenon of such universality among organisms, and yet not recognized outside of organisms, must have some deep biological significance. Though in the past half-century great advances have been made in our knowledge of the details of sexual reproduction, we have not advanced far in our knowledge of the essential nature of that protoplasmic dimorphism which is sex.

About the nature of that essence of sex one can only frame hypotheses. One thinks of the double nature of matter—positively charged and negatively charged. One thinks of the dimorphism of certain organic materials, such as dextrose and levulose. Other hypotheses could be framed and doubtless have been. But material adequate for testing these hypotheses has hitherto been lacking. The ordinary animal or plant is a nutritive, growing, perhaps moving and sensory organism, besides being a sexual organism, and the sexes differ greatly in their other functions and in their form. The Carnegie Institution is in a peculiarly favorable position, since it possesses an organism supposed by some to be sexless until Dr. Blakeslee discovered that it was practically all sexual. Since this discovery Dr. Blakeslee has preserved and carried on these sex-strains for 20 years and has brought them with him to this department. This organism is the bread mold—*Rhizopus*. It consists of a mass of threads which under certain conditions may unite to form reproductive bodies. There is no difference in form between the male masses and the female masses. Apparently one mass of threads, which may be increased to any desired amount, is all male throughout its whole extent; another mass of threads is all female throughout its whole extent. The male and the female masses are alike; the only way of telling which is which is by bringing two masses into contact. If they react by forming sexual bodies they are of different sex; if they fail to react they are of the same sex.

Now, this organism presents in its simplest form material upon which to study the fundamental nature of sex. This Institution has the unique opportunity to utilize this material and if successful in its search, it would have to its credit one of the greatest discoveries in biology. Dr. Blakeslee is still maintaining his strain of mucors. He has during the past year accumulated additional data, especially from the "imperfect hybridization" reaction, which increases the evidence of a strict sexual dimorphism in this group.

The Nature and Metabolic Basis of Sex in Pigeons.

During the year Dr. Riddle has completed his study of the differential survival of male and female dove embryos, subjected to increased and decreased pressures of oxygen. A summary of the results is given in tables 4 and 5, described by Dr. Riddle as follows:

"Table 2 shows that the treatment with high concentrations of oxygen killed a lower percentage of males, a higher percentage of males survived, and the total number of males obtained is disproportionately high. Treatment with reduced pressures of oxygen killed a higher percentage of males, a lower percentage of males survived, and fewer males than females were ob-

TABLE 2.—*Summary of data from experiments with altered oxygen pressures and low temperatures.*

Nature of treatment.	No. of embryos tested.	Embryos.		Sexes.					
		Killed.	Survived.	Killed.		Survived.		Total.	
				♂	♀	♂	♀	♂	♀
Increased O_2:									
Totals.....	865	349	516	16	14	271	209	287	223
Per cent...	....	40.3	59.7	5.6	6.3	94.4	93.7	128.7	100
Decreased O_2:									
Totals.....	782	348	434	34	22	190	240	224	226
Per cent...	....	44.5	55.5	15.2	9.7	84.8	90.3	99.1	100
Cooling:									
Totals.....	438	222	226	34	21	106	113	140	134
Per cent...	....	48.4	51.6	24.3	15.7	75.7	84.3	104.5	100

tained from the treated eggs. The data obtained from the subjection of embryos to low temperatures are in most respects similar to those obtained from reduced oxygen pressures, but the resulting sex-ratio certainly departs less from the normal and fewer and less significant numbers are available. Since embryos of known sex were killed in only about half of the experiments, it is statistically more correct to calculate percentages for 'killed' and 'survivors' upon the numbers of males and females found in these experiments alone. This calculation is supplied in table 3, where the order or nature of none of the comparisons made above is changed by the second method of calculation.

"These experiments, therefore, afford some evidence (hitherto entirely lacking) that a metabolic sexual difference characterizes male and female dove embryos. And the resulting metabolic difference here indicated for the embryos is in complete accord with the metabolic difference which our previous work with pigeons has shown to characterize the ova and the adults."

TABLE 3.—*Summary excluding experiments in which no "sexed" embryos were killed.*

Nature of treatment.	No. of embryos tested.	Embryos.		Sexes.					
		Killed.	Survived.	Killed.		Survived.		Total.	
				♂	♀	♂	♀	♂	♀
Increased O_2:									
Totals.....	448	238	210	16	14	107	79	123	93
Per cent...	....	53.1	46.9	13.0	15.1	87.0	84.9	132.3	100
Decreased O_2:									
Totals.....	440	225	215	34	22	83	109	117	131
Per cent...	....	51.1	48.9	29.1	16.8	70.9	83.2	89.3	100
Cooling:									
Totals.....	333	187	146	34	21	69	73	103	93
Per cent...	....	56.2	43.8	33.0	22.6	67.0	79.5	110.8	100

CONTROL OF THE SEX-RATIO.

Very significant departures from the typical 50–50 sex ratio are frequently found, and more rarely the extreme case of 100–0 appears either in nature or in experiments conducted in the laboratory. When the latter ratio can be regularly produced, sex-ratio is said to be controlled. Control of the sex-ratio offers an interesting field for experimental research, the importance of whose applications to man are obvious.

Cladocera.—In the Year Books for 1917 (p. 119) and 1918 (p. 107) have been described Dr. Banta's attempts to control the sex-ratios in these small crustaceans. This year further progress has been made and all species or strains which were adequately tested yielded greater or less evidence of sex-control, or at least an influencing of the sex-ratio. While in 1917 the addition of acid yielded "all male" broods, this year the method used was that of crowding the mothers by placing 10 or more in a bottle containing approximately 75 c. c. of culture water. Such crowded mothers produced from a small percentage to over 90 per cent males in individual bottles. The species used were *Daphnia pulex, Simocephalus exspinosus*, and *Moina macrocopa*. Ordinarily in nature they produce few or no males.

TABLE 4.—*Summarized data of some Cladocera sex-control experiments. Number of offspring of each sex, and percentage of male offspring.*

No. of mothers, per bottle.	2			10			20		
Species.	No. of ♀♀	No. of ♂♂	P. ct. ♂	No. of ♀♀	No. of ♂♂	P. ct. ♂	No. of ♀♀	No. of ♂♂	P. ct. ♂
Daphnia pulex	245	0	00.0	385	176	31.4	276	19	6.4
S. exspinosus	149	0	00.0	42	42	50.0	41	88	68.2
Moina macrocopa	476	57	10.7	643	688	51.7	1,021	964	48.6
All three species	870	57	6.1	1,070	906	45.8	1,338	1,071	44.5

From table 4 it appears plain that the proportion of males increased enormously in the bottles with 10 or 20 females, as compared with those containing only 2 females. The most probable explanation seems to be that crowding, probably by influencing the quality of the water, induces male production. Dr. Banta reports further:

> "The different species and lines vary in their susceptibility to the sex-control measures. The above are representative data of the sex-control experiments. *Moina macrocopa* is perhaps the most responsive of the species used, though the two experiments with *S. exspinosus* gave slightly higher male percentages. *Daphnia pulex* is the least responsive species so far sufficiently tested and different lines of this species vary in their susceptibility to the influence of crowding.
>
> "One line of *Daphnia pulex*, when subjected to crowding, has so far produced sexual eggs (ephippa) rather than males. This is again suggestive of differences in susceptibility of the different lines to the same influence. The influence calling forth the production of males is obviously related to the production of ephippial eggs, else the whole mechanism of sexual repro-

duction in Cladocera must miscarry. Yet the same influence may in one case call forth males and in another case sexual eggs. Since males and not ephippial eggs appear in most of our cases and ephippial eggs and not males in the other case, evidently somewhat different conditions must be obtained to produce ephippial eggs where males are now obtained and males where ephippial eggs have been obtained."

Differential viability of "male" and "female" sperm.—As noted in previous Year Books (1919, p. 135, 136; 1920, p. 124–127), Dr. Little has been carrying out researches in this field.

"In last year's report the suggestion was made that a differential viability of the male-forming and female-forming sperms might underlie the various departures from an equality sex-ratio which are commonly met with and which are especially marked in first litters or first births and in first-generation hybrids between various strains and races of laboratory mammals and different nationalities in man. During the summer Mr. Felix Saunders, Miss Isabelle Graves, and Miss Vera Goddard have been working under Dr. Little's direction on methods and technique of obtaining the hydrogen-ion concentration of the seminal fluid, vaginal secretions, and uterine secretions in rats and dogs. For this purpose female rats of known stage in the œstrous cycle are obtainable by a daily analysis of the laboratory colony, by the methods used and described by Long and Evans. The Bovie self-recording potentiometer is being used for the determination of the hydrogen-ion concentration and special methods have been devised by which it is hoped that readings may be obtained from secretions while they are still within the vagina or the uterus of the female."

Differences in size between "male" and "female" sperm.—It is known that in mammals and some insects the sex of offspring is determined by the one of two unlike types of sperms that fertilizes the eggs. The two types differ in the number of chromosomes. Some years ago C. Zeleny, Faust, and Senay (1915) showed that certain spermatozoa differ also in size and fall into two overlapping groups of head-length. It was important to know if the same is true of mammalian sperm. Under Dr. Little's direction, Miss Graves and Miss Goddard have measured and tabulated the head-length of over 1,300 unstained dog sperm, all obtained from the same animal. A magnification of 2,000 times was used. To secure accuracy, camera-lucida projections were drawn and then measured.

When tabulation of the results was made by division into classes of 0.25μ, the bimodal curve is not obtained which one expects if there are two size-types. If two modes are actually present they are masked by being so close together that the methods available for measuring sperm fresh from the animal are not accurate enough to establish their existence beyond doubt. The personal error introduced by the observer would probably be fully as great as the distance between the modes. The difference between the two types of sperm in dogs is not sufficiently large to measure in material as nearly as possible in the actual condition of its entrance into the female reproductive tract.

It is probable, therefore, that explanations for departure from an equality sex-ratio which are based on mechanical advantages of one or the other type of sperm because of its *size* are not well founded.

The effect of staleness of sperm on the sex-ratio.—Students of Amphibia have laid stress upon staleness of gametes as a factor in the production of an excess of males. It has been suggested that stale sperm might affect the sex-ratio in man. To test this matter, Miss Jane Hubbard, working under Dr. Little's direction, is using the northern squash beetle, *Epilachna borealis.* In this species copulation occurs only once, while such a female lays its eggs throughout the summer season. At the end of the season the eggs laid must have been fertilized by sperm that has been retained by the female for months. The work is not finished. Table 5 gives the totals of observations made to the date of report.

TABLE 5.—*Numbers of female beetles (Epilachna borealis) confined during 1921, number of eggs laid, number of larvæ, of pupæ, and of imagines resulting from them.*

The data are given for the experimental lines and for 3 control lines.

	No. of beetles.	No. of eggs.	No. of larvæ.	No. of pupæ.	No. of imagines.
Experimental lines	43	3,811	1,385	86	10
Control lines (males retained)	15	1,036	403	23	15
Control lines (males changed)	18	762	222	1	0
Control lines (general)	30	1,165	825	192	136

The work is being continued; it is too early to announce results. The heavy mortality of the experimental lines is striking.

SELECTION OF SEX-INTERGRADES IN DAPHNIA.

Dr. A. M. Banta has, with the assistance of Mr. L. A. Brown, continued changing the proportional degree of sex-intergradation in his interesting biotype of *Daphnia longispina* (see Year Book 1920, p. 12). He reports the main results of the year in this topic:

"An effect of selection has been obtained wherever attempted with intergrades of *Daphnia longispina.* With strains I and III, originating from sisters, the effect of selection appeared after six generations of selections, during which the stock was reared under uniform conditions. The curves for the two strains fluctuate considerably, but the divergence between them is never eliminated. (Really the selection is only in the low strain, III, since the high strains can not be maintained too high because of consequent low productivity and ultimate sterility.) Return selection has also been effective in every one of the 10 cases in which it has been carried out, though it has not been effective with equal promptness or to an equal degree with the different strains. Strains X and XXII are returns to high from low. Strain XXII is less successful as a return selection than strain X, but it materially diverged from strain XII, from which it was derived. We have obtained through selection a divergence between two selected strains; a return from high to low and back to high again, and a return from low to high and back to low again.

"The question arose as to whether these strains really possessed genetic differences or whether their differences were merely of a cytoplasmic nature. To test this, several high mothers from strain I were simultaneously given the same treatment as an equal number of mothers *of the same grade* from low strain III. The offspring of each set of mothers were carefully graded. The result was as follows: the mothers of low strain III with a weighted average grade of 24.9 produced young averaging grade 7.7, while the mothers from high strain I, with a weighted average grade of 26.0, produced young averaging grade 25.3. Hence, while the mothers were of as nearly equal grade as could readily be obtained, the offspring from the mothers belonging to the low strain graded only one-third as high as offspring from the high strain. This would seem to indicate clear genetic differences between the two strains, and all the other evidence supports this conclusion.

Another question that arose concerned the possibility of separate genetic factors being involved in the development of the different secondary sex-characters. This was tested by selecting different strains for different individual secondary sex-characters. For example, in strain XVI individuals were selected which had the most male-like antennules, while in respect to other secondary sex-characters they were only moderately intergrade. The result of selection on this basis for 10 generations and with 3 strains was entirely negative. The secondary sex-characters are obviously transmitted as a whole and not by separate factors for character of individual secondary sex-characters—antennules, breast margins, etc.

"Environmental influences affect the degree of intergradeness of secondary sex-characters in sex-intergrade stock. At certain times all the stock is relatively highly intergrade; at other times it is all relatively less intergrade. For example, in the 31st and 42d generations of selection are general uplifts in the curves of intergradeness indicating increased degree of intergradeness during those generations. In the 53d generation a general dip in the curves followed by a rise in the next generation indicates lessened followed by increased degree of intergradeness. These simultaneous fluctuations are reflections of environmental factors."

SEX-INTERGRADES INDUCED BY PARASITISM.

Sex-intergrades are found in Crustacea that are parasitized and rendered sterile. Such parasitized Crustacea have been described by Giard (1886–88) in the case of several higher Crustacea and by Geoffrey Smith (1910) in the spider crab *Inachus*, parasitized by *Sacculina*. During this year this phenomenon has been found by Dr. Banta in the "new form" of *Daphnia pulex* obtained near Cold Spring Harbor. He reports:

"The secondary sex-characters in *D. pulex* are very similar to those of *D. longispina*, which are figured in Year Book No. 16 for 1917, page 123. In these parasitized individuals Dr. Banta found that the sex-intergrade condition varied from only slightly intergrade to rather highly intergrade in character. If a larger series could have been secured it seems probable that most of the features of the *D. longispina* intergrade stock would have appeared. Enough was seen to make it clear that (1) in the characters affected, (2) the range of degree of intergradeness in different individual intergrades, and (3) the lack of uniformity in degree of intergradeness in the different characters in the *same individual*, the parasitized *D. pulex* intergrades closely resembled the intergrade *D. longispina*. All of the *D. pulex* intergrades that could be found were carefully cared for, but all were parasitized and died within a few days. A few other individuals of the same material were also parasitized and yet possessed normal secondary sex-character. The infection may have reached these individuals too late in life to affect their secondary sex-characters. Inasmuch as all the intergrades were parasitized, it is believed that the intergrade condition was the result of parasitism. This has considerable theoretical interest. It is a case of an apparently purely somatic effect which most strikingly resembles the effect of genetic factors in other similar material. The general resemblance of the parasitically produced intergrades of *D. pulex* and the genetically produced intergrades of *D. longispina* is so striking that except for the species-character differences and the presence of parasites in the former it is doubtful if we could distinguish intergrades of the two classes."

INHERITANCE OF SPECIAL TRAITS.

FLOWERING PLANTS.

Rudbeckia.—Dr. Blakeslee has published "A chemical method of distinguishing genetic types of yellow cones in *Rudbeckia*," in the Zeitschrift für induktive Abstammungs- und Vererbungslehre. He describes his discovery of the two strains of "yellow daisy" with a yellow instead of a purple cone. These were indistinguishable in the field, but dipped in alkali the flowers of one race turn black, the other red. When black-yellow is self-pollinated, only black-yellow is produced; when it is pollinated with ordinary purple heads all progeny are purples in F_1, and in F_2 purple and yellow appear in the proportion of 3 : 1. The red-yellow behaves similarly. When the black-yellow and red-yellow are crossed, the offspring are all purple in F_1, and purple, red-yellow, and black-yellow again in F_2. This work is probably the first where a sharp chemical distinction has been possible between the genetic groups within one phenotype.

Portulaca.—The development of the experiments with *Datura* has made it necessary to reduce work on *Portulaca*. Dr. Blakeslee has, notwithstanding, secured important additional data regarding the inheritance of color types in the flowers, and has found that dark stigmas are dominant to light ones and dark pollen to light. The frequent "somatic mutations" are, however, the chief point of interest. Rather unexpectedly, nearly all of these mutations have arisen in dominants that have arisen from reversion, and hence appeared first in the heterozygous condition. Dr. Blakeslee reports that:

"The possibility of such mutations being reversible has been investigated. For this purpose a pedigree was chosen showing a 1:2 :1 ratio for yellow and white petals, with the heterozygotes distinguishable from the homozygous yellows by a less intense pigmentation. The parent of this pedigree had arisen the previous year as a periclinal chimera from an inbred white line which shows frequent mutative striping with yellow. Of over 5,000 heterozygous yellow flowers examined, Miss Bergner, assisting Dr. Blakeslee, found 3 which showed white flecks and 1 which showed a dark yellow fleck which was presumably homozygous for yellow. The evidence seems conclusive, therefore, that the somatic mutations occur in both directions, to dominants and to recessives. It is impossible to give reliable figures for the relative frequency of mutation in the two directions, since, although yellow flecking on whites seems relatively common (89 yellow-flecked flowers out of over 2,500 examined), white flecks on yellows are less readily discernible."

SAP PROPERTIES OF EGYPTIAN AND UPLAND COTTON AND OF THEIR F_1 HYBRIDS.

Preliminary observations at Sacaton, Arizona, in 1920 indicated that Egyptian and Upland cotton differ in their sap properties (Year Book, Carnegie Inst. Wash. 1920, p. 143). Careful plantings were made at the Cooperative Testing Station at Sacaton, through the courtesy of Dr. T. H. Kearney, for the purpose of a more exact comparison of Meade and Acala Upland Cotton with Pima Egyptian cotton, and of the F_1 hybrid between Pima and Meade with the two parent species. The work on the sap properties of these four series of plants occupied the attention of Dr. Harris, with the assistance of J. V. Lawrence, W. F. Hoffman, A. T. Valentine, and Mrs. J. V. Lawrence during the month of August.

SUSCEPTIBILITY TO INOCULABLE CANCER.

Heredity of susceptibility.—In the last annual report, evidence was offered by Dr. Little to show that in all probability from three to five Mendelizing factors were involved in determining the susceptibility and non-susceptibility of hybrids between Japanese mice and albinos to a sarcoma J. W. B. of the Japanese mice.

During the past year adeno-carcinomas dbrA and dbrB have both been used by him in a series of genetic experiments involving a cross between the susceptible dilute brown race and a non-susceptible albino race. Both parent races were inbred—the dilute brown race especially so. F_1 hybrids between dilute brown and albinos grew both the A and the B tumors in every case. The tumors were implanted subcutaneously on the opposite sides (axillary regions) of the animals used. The result given by the F_1 mice was expected and predicted, since the degree of inbreeding of the dilute brown race was so great that the gametes contributed by various individuals from it to the F_1 hybrids were essentially alike. They each presumably contained in a simplex condition the genetic factors which together form the "dilute brown" complex and which, therefore, bring about the favorable treatment of implants of the dbrA and dbrB tumors.

In the experiments involving the Japanese mice and albinos, the parent stocks were so widely divergent from one another biologically that it is not at all surprising that the number of Mendelian factors underlying the difference was found to be large. (In the case of the epithelial tumor, carcinoma J. W. A., it was estimated at 12 to 14.)

In crosses between albinos and dilute browns, however, the difference should not be nearly so great, and the number of factors should therefore be distinctly smaller.

The behavior of the F_2 hybrid generation which has been raised and observed by Dr. L. C. Strong is in complete accord with this expectation. The B tumor gives a total of 108+ to 89−. If a two-factor difference is involved, a 9 : 7 ratio is expected. This, in the number of mice involved, would mean 110.7+ to 86.3−. The dbrA tumor is the same which, by extensive tests with non-susceptible wild house-mice, Dr. Strong found showed significantly fewer indications of growth than did tumor dbrB. The genetic behavior of this tumor gives an interesting clue to the nature and extent of its divergence from tumor B. 88 animals of F_2 are plus to tumor A and 110 are minus. On a three-factor basis of 27:37, the numbers expected are 83.5+ to 115.5−.

The back-cross of F_1 by albino produced corroboratory evidence in each case. Thus, in this generation, tumor B gives 10+ and 44−, the expectation on a two-factor basis being in this case 13.5+ to 40.5−. Tumor A gives a total of 8+ to 46−, the expectation being 6.75 to 47.25. The conclusion can, therefore, be drawn that in the inheritance of susceptibility and non-susceptibility to the B tumor, a *two*-factor difference between the dilute brown and albino race is involved, while for the A tumor *three* factors are concerned. This drives the work with inoculable tumors a point nearer to the isolation of animals and strains differing in a single Mendelian factor.

Miss Helen Bloomer and Miss Marie Poland have assisted in the genetic work during the summer. More than 200 hybrids other than those recorded have been inoculated and are awaiting observation, while a total of more than 1,200 hybrids are now available for breeding.

Dr. Strong, who has practically completed the work on inoculation of wild mice with tumors dbrA and dbrB, reports as follows:

"Several points of genetic interest appear to be brought out by this experiment. Among these is the fact of which preliminary mention was made last year that physiological tests are more delicate than histological ones in that they record slight differences in the tissue of two tumors, which were histologically indistinguishable.

"The experiment is a continuation of the one mentioned in the previous report. At present the data relative to this point are as follows:

Total dbrB 876. Negative: 80±5.68 reactions or 9.23 per cent ±0.66. reactions
Total dbrA 705. Negative: 15±2.55 reactions or 2.08 per cent ±0.35. reactions
Difference 7.15 per cent ±0.74

The difference is thus 9.66 times its probable error.

"The susceptibility curve during the full age-cycle for gonadectomized individuals is quite distinct from that of the unoperated controls.

"Susceptibility is influenced by several general factors, among which age is one of the most important. The present experiment confirms a similar one carried out by Dr. Little with sarcoma J. W. B. It, however, goes further in that it includes individuals from all age classes. In animals of a *non-susceptible race*, the maximum reactive potentiality against a tumor is attained by a gradual process at the period of sexual maturity. With advancing old age non-susceptibility decreased somewhat. These data have a direct bearing upon the nature of the individuality of the organism. The age-cycle susceptibility curve for gonadectomized individuals is, as may be expected, the direct reverse of that for the normals.

"Another point of minor importance is the fact that there is no differential effect of gonadectomy upon the two sexes, thus indicating that the gonads are a determining factor in the process of differentiation for both sexes.

"The conclusions to be drawn from the complete experiment naturally group themselves under two headings: (*A*) the activity of the tumor cell; (*B*) the reaction of the host.

"(*A*) The activity of the tumor cell. (1) There is, in some cases at least, a uniform reaction, providing the tumor is transplanted into individuals of the *same age and sex of a relatively homogeneous series of hosts.* In other words, no rhythms of tumor growth are encountered. (2) A transplanted tumor grows progressively (within limits) at a fairly uniform rate of development if placed into definitely proven homogeneous mice (dBr stock and F_1 hybrids). Sudden fluctuations in growth activity may sporadically occur, due to a process analogous to mutation.

"(*B*) The reaction of the host. (1) Race is the primary factor that determines whether or not a given individual shall or shall not grow the tumor mass progressively. Susceptibility and non-susceptibility are manifestations of the genetic constitution of the individual. (2) Several secondary physiological factors, among which age is the most important, function in determining the outcome of a given reaction. These may be called contributory or accessory factors. (3) The age factor is an expression of the degree of the process of the assumption of tissue specificity controlled to some extent by the activity of the gonads. (4) The age-susceptibility curve towards transplantable tumors for normal individuals of a *non-susceptible race* bears a remarkable similiarity to the curve of activity of the gonads. (5) The sex factor (encountered especially with young mice in development) depends upon at least two primary causes: (*a*) the age factor, and (*b*) the difference in physiological activity between the sexes at the different age-periods of life. (6) Removal of the gonads does not change the massed percentage reactions for individuals of a *non-susceptible race.* This bears out the previous conclusions that the number of percentage reactions in a given strain depends upon the genetic constitution of the individuals. (7) Gonadectomy produces, in the stock employed, a significant increase in percentage reactions in mice attaining sexual maturity (age class 3). (8) Gonadectomy causes an approach towards a neutral type (loss of characteristic differences between sexes) in the percentage of reactions towards both tumors used, just as it does in the case of morphological characteristics (Hatai and others). (9) By the removal of the gonads, the individuality of the tissues and the normal functioning of the age factor can be interfered with. (10) A severe shock, caused by such an operation as gonadectomy, produces, in some cases at least, a resistant state to transplantable tumors that is at its maximum from 5 to 10 days after operation."

Receipt of sarcoma 180 from the Crocker Research Fund.—During the early summer, mice with implants of Crocker Fund sarcoma 180 were received by this Department, through the kindness of Dr. F. C. Wood, the director of the Crocker Research Fund. Preliminary experiments by Dr. Strong have shown that this tumor grows in a very high percentage of mice inoculated. A few wild mice which are non-susceptible have been obtained and experiments will at once be started to determine the genetics of susceptibility and non-susceptibility of this tumor.

Inoculation of mice of the genera Peromyscus and Microtus.—Miss Pearl Anderson and Miss B. W. Johnson have, under Dr. Little's direction, trapped and inoculated with tumors a number of mice, both *Peromyscus novemboracensis* and *Microtus pennsylvanicus.* The tumors used have been adenocarcinoma dbrA, dbrB, and sarcoma 180. None of the mice grew any of the tumors progressively, but certain of them showed indications of a mass at the site of inoculation. Table 6 shows the percentage of indications (+) for the two genera and the three tumors. There was no evidence of stimulation of the host tissue to neoplastic growth.

TABLE 6.—*The absolute number of field mice of each of two genera in which an indication of the inoculated tumor remained (+) and in which no indication remained (—); also the percentage of persisting indications.*

	dbrA			dbrB			Sarcoma 180.		
	+	−	P. ct. +	+	−	P. ct. +	+	−	P. ct. +
Peromyscus........	1	51	1.92	2	20	9.09	6	37	13.9
Microtus..........	7	33	17.50	......	......	....	4	52	9.13

Preliminary work on the isolation of single tumor cells and on the mechanics of metastasis.—During the summer, Mr. George O. Gey, of the University of Pittsburgh, has worked in Dr. Little's laboratory on the isolation and implantation of minute particles of tumor tissue, with a view to isolating single tumor-cells if possible. The preliminary phases of the technique have been thoroughly gone into and the work will be continued throughout the year at Pittsburgh by Mr. Gey. Miss Margaret Schneider has also assisted in this work.

An interesting piece of evidence as to the mechanics of metastases was obtained by Mr. Gey in the course of his work. He reports somewhat as follows:

"Tumor emulsion filtered through fine gauze was inoculated through an hypodermic syringe into the liver of 5 mice. The dosage ranged from 0.2 c.c. to 0.3 c.c. of filtered emulsion. Great care was taken throughout the operation to maintain as aseptic conditions as possible. In every case the mice were killed 14 days after inoculation. All showed abnormal appearances of liver, kidneys, and spleen. The two controls which remained available for observation had been inoculated subcutaneously and both showed tumors.

"In the experimental animals histological examination showed that the sarcoma *has definitely invaded, through the medium of the blood, the liver, kid-*

ney, and spleen. Nodules of tumor cells occurred in these organs surrounded by normal tissue. In some cases it could clearly be seen that the tumor cells surrounded or lay close to a blood-vessel."

In these cases, therefore, it seems clear that a transfer of minute groups of cells or of single cells has taken place through the blood-system. An interesting line of investigation concerning the course and mechanics of metastasis is thus suggested.

Spleen implants in mice of different strains.—A series of experiments has been conducted by Dr. Little and Miss B. W. Johnson to investigate the method of inheritance of favorable or unfavorable reaction to subcutaneous implants of spleen tissue. The material used for this consisted of two races of mice. The first of these was a strain of Japanese waltzing mice which had been subjected to the closest inbreeding for approximately 15 years. This is the Lambert strain already described in connection with work on inheritance of susceptibility to transplantable tumors.

These animals are, as a result of the long-continued inbreeding, remarkably uniform genetically. It is a well-established fact that if a piece of the spleen of a mouse be transplanted subcutaneously in the same animal (autoplastic implant), the implant will persist and a blood-supply will be established. In other words, the animal does not treat the implant as a foreign body, but attempts to nourish it even in an unaccustomed position.

If a piece of the spleen of another unrelated animal of the same species is placed beneath the skin (homioplastic implant), the host *usually* reacts unfavorably to the implant, treating it as a foreign body, and by leucocytic action or invasion of connective tissue succeeds in eliminating the implant.

Theoretically, when animals have been inbred for a considerable period they become, as above stated, remarkably homogeneous genetically. This should mean that when a homioplastic implant is made between two such genetically similar individuals the conditions will approximate or be equivalent to those of an autoplastic implant. Work already reported by Little and Tyzzer on the transplantable tumors J. W. A. and J. W. B. shows that the Japanese waltzing mice of the Lambert strain fulfill the requirements of genetic uniformity to a marked degree by growing subcutaneously implants of the tumors which originated in animals of that race.

When the Japanese tumors were transplanted into individuals of an unrelated race of albino mice, an occasional individual supported the implant for a short time, but the final result was in every case negative.

If the Japanese mice are essentially homogeneous genetically, the hereditary factors carried in their gametes should be essentially the same. Implants of Japanese-mouse tumor in first-generation hybrids between Japanese and albino mice grew in all cases. This showed that the genetic factors received in the gamete from the Japanese parent were sufficient to cause the F_1 hybrids to react favorably to Japanese-mouse tissue.

The same situation should be found to exist with reference to splenic implants. The F_1 hybrids between Japanese mice and albinos should grow implants of the Japanese-mouse spleen quite as successfully as they grow their own. On the other hand, the Japanese mice should grow implants of their own spleens, but should eliminate those from F_1 mice, since they contain none of the complex of genetic factors which characterize the albino race, and which are in some degree present in the F_1 animals.

Actually, this is found to be the case. 33 F_1 mice inoculated simultaneously with their own and with Japanese waltzing-mouse spleen grew both implants successfully, as expected; 23 Japanese mice, 20 days after inoculation, were growing the implants of their own spleen, but had eliminated or were eliminating the implants of F_1 spleen.

This completes satisfactorily the first experiment of a series designed to obtain evidence concerning the nature and method of inheritance of the genetic factors underlying the physiological differences between individual mammals. L. Loeb has recently advanced an hypothesis of "auto-syngenesio-, homoio-, and species-individuality differentials" to explain somewhat similar cases. The work here reported indicates strongly that a simpler and more consistent explanation exists.

Histological preparations confirmatory of the macroscopic observations of the transplanted tissues have been obtained by Mr. W. F. Windle, of Denison University, working during the summer with Dr. Little. Three papers covering this series of experiments from genetic, medical, and histological viewpoints are now in preparation.

Genetic Studies in Cats.

In 1920, Doncaster suggested that the occurrence of tortoise-shell males in cats and their usual sterility might be due to a process of hormone action somewhat similar to that involved in the production of free martins in cattle. During the past year, through the courtesy of the Society for the Prevention of Cruelty to Animals in New York City, it has been possible for Miss E. E. Jones to examine the uteri of 140 pregnant female cats. In a total of 589 embryos, no sign of anastomosis of the circulatory systems supplying the fetuses has been discerned. The work provides a considerable body of negative evidence against the correctness of Doncaster's hypothesis.

White coat color in cats has for some time been recognized as a probable Mendelian dominant representing an extreme form of spotting. Since a factor with somewhat the same function in mice has been found by Little (1915) to behave as a lethal when present in a duplex condition, it was thought to be worth while to determine whether there was a significantly higher proportion of degenerating fetuses in pregnant white females than in non-whites. White cats are not common, and the chance of obtaining pregnant animals is, therefore, not great. Nevertheless, 84 embryos have been observed in such females, and of these 10, or 10.64 ± 1.86 per cent were degenerating. In 505 embryos of non-white females, 18, or 3.44 ± 0.51 per cent were degenerating. The difference is 4.02 times its probable error. The conclusion is warranted that *a significantly greater number of degenerating embryos are found in white than in non-white female cats.* Since the sires of these litters were probably, in the great majority of cases, non-white, *it is likely that, in some white females at least, a lethal action of some sort is operative when the factor for white is present even in a simplex condition.*

Eyelessness in Cladocera.

Many cave animals are eyeless. The most satisfactory explanation of this relation is that an eyeless mutation occurred in such species before they became cave inhabitants; that the eyeless descendants of such mutations were able to take advantage of caves and survive in them. Cases of eyeless sports are, accordingly, of special interest to us. In 1919 an eyeless *Simocephalus exspinosus* was observed from one of Dr. Banta's cultures, but she had, unfortunately, already been killed. This year two eyeless *Moina rectirostris* appeared in the cultures, lacking the optic ganglion as well as the ommatidia, and having a head-form that was changed accordingly. Many young were obtained from each of these individuals and all possessed fully developed optic structures. Likewise, more than 5,000 sibs and descendants of the eyeless individuals were examined. All possessed eyes. Obviously these two cases were merely accidents in development. Since, however, eyelessness is inherited in *Drosophila,* it seems justifiable to continue the search for eyeless Cladocera.

Clones in Cladocera.

A study by Dr. Banta, as yet uncompleted, seems to indicate that the obviously different forms of *Simocephalus serrulatus* which he has found in different parts of the United States may be further differentiated into clones differing by more minute physiological or morphological characters. This matter has been more fully worked out for strains of *Daphnia pulex,* in which at least three distinct clones, formerly unsuspected, were differentiated from our laboratory stock. The recognition of additional clones in this material probably depends merely upon a further refinement of our measurement and observations of the different strains. This work is to be carried further.

Genetic Basis of Animal Behavior.

Heredity of behavior in dogs.—As stated in the last report of this Department (Year Book, 1920, p. 137), we have undertaken a study of the factor of heredity in the behavior of dogs. This study is being conducted by Dr. E. C. MacDowell. He reports progress as follows:

In attempting to discover the laws controlling the inheritance of a tendency to specific behavior by following the course of such tendency through crosses and successive generations, the first and most difficult problem is to find suitable methods of recognizing the specific behavior when manifest. Once such methods are formulated, the work can proceed with certainty to a successful conclusion, however long and tedious may be the road. In discovering suitable methods distinct progress has been made at this Station. The first apparatus designed to measure the behavior and educability of dogs has been in operation since the beginning of the year. Its main object has been to provide a simple method of testing the responsiveness of different individuals, and, more especially, different breeds, to various types of signals. So far the work has been restricted to one breed of dogs, namely, dachshunds. Instead of learning to follow a certain path, the dogs were given the problem of learning to choose between alternative paths according to signals, that is, to form the association between a certain signal and their food. An important feature of the apparatus (see figure 3) is the arrangement which permits the dogs to leave their kennels and go through 10 or more trials a day without seeing the observer. The observer remains in the closet *O*, where the records are made and from which all doors and signals are operated. By means of mirrors, electric signals, peep-holes, and the sounds made by the dogs themselves, the course of the animals can be followed. The kennels are provided with sliding doors which are opened by long cords. Released from his kennel, the dog to be trained passes over the gangway to the house through the opened door *F*, which is closed behind him, on to door *M*, which is also open. When he reaches the end of the central alley the signal is given at the right or left side of the house. If the association has been formed the dog will turn towards the signal and continue around to the side alley (doors *Pl* and *Pr* always being open); by stepping on the board *L* or *R* a light signal is given in *O* for the observer to open the next door (S_L or S_R) into the food compartment. Door *S* is immediately lowered again, a morsel of food dropped into the food compartment by a device operated from *O*, and, after eating, the dog leaves this compartment by door *E* and thence to *M* and through the apparatus again. This is continued until the desired number of trials has been run (10 per day), when the dog finds *M* closed and leaves the house. If a wrong choice is made in the trials, that is, if a dog turns away from the signal, the door *S* on that side will not be opened and the dog must correct himself by going to the opposite side. In order to prove that a real association, and not merely a rhythm, has been formed, the signals are given on one side or the other according to the order of the red and black spots in two well-shuffled packs of playing cards. It is obvious that half the choices will be correct by chance even if no association at all is formed. The long series of daily trials is given to obtain a more reliable measure of the proportion of correct choices.

The first signals used were electric lights, located at the ends of the transverse alley, visible when the dog reached the end of the central alley. Although the house was not completely dark, the transverse alley was sufficiently in shadow to make a great contrast between the illuminated end and the opposite one. The first litter to be trained in this apparatus included 5 one-year-old dachshunds (ex Cocoa by Engadin); they adjusted themselves immediately to the routine of the apparatus. The mother, Cocoa, was trained at the same time and showed the same adaptability to the apparatus. Some of these learned to return to their kennels when they found door *M* closed after their last trials; others had to be ordered back. But the association with the light signal was not clearly formed in any case, although the trials were continued for over 2 months.

A second type of signal has been used. A common electric buzzer was placed close to each door, S_L and S_R. No attempt was made to have these even approximately similar in sound. Although a tendency to turn away from the buzzers appeared at first, it was only a short time before the association was started in most cases. Without presenting any exact data, it seems clear from the above that these dachshunds respond to sound more readily than to light signals.

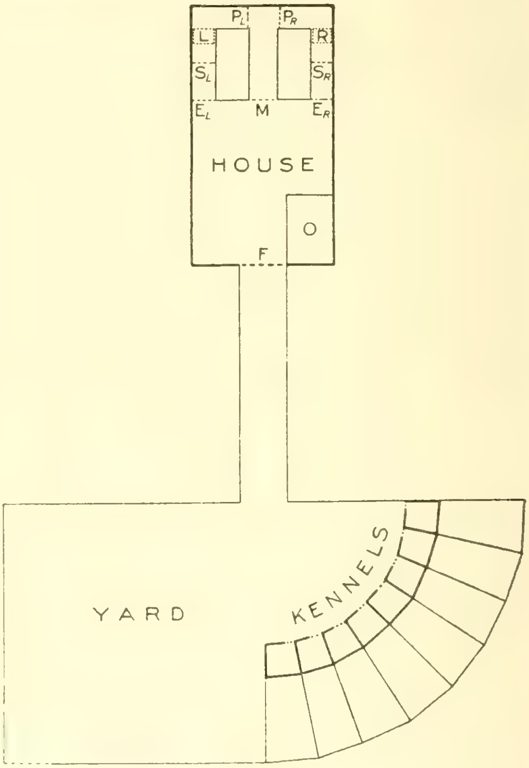


Diagram of the association apparatus. The kennels are arranged so the dogs can be released and approach the apparatus in the house without seeing the operator. Dotted lines represent doors; O, observers' closet, from which all doors are operated; M, entrance to apparatus; P_L and P_R, punishment doors normally raised; L and R, boards making electric contacts when touched to give a signal in O for opening the doors S_L or S_R which lead into the food compartments; E_L and E_R exit doors. The problem consists in learning to turn at the end of the middle alley towards a signal which is given at random on the right or left side. Light and sound signals have been used.

Fig. 3.

A second litter from the same mother (ex Cocoa by Prince) and one pup from a different mother and the same father (ex Betty by Prince) have been introduced to this apparatus. These dogs have been under the charge of Mr. Snyder during the summer. Their father, Prince, is an exceedingly sensitive dog, seemingly timid and with little aggression. For a week the attempt was continued to get him to go through the apparatus, but in this time he showed no signs of modifying his fear of the apparatus or of the movement of the doors. He is an older dog and his necessarily different experiences in life keep him from being directly comparable with the first set trained, so the behavior of his offspring is of especial interest in interpreting his reactions. The preliminary training of accustoming these pups to go to the house for food went along successfully, but just as soon as the doors of the apparatus were moved and the buzz signal was given, they were all much bothered. Not until after 3 weeks of daily training were the dogs in this litter going through the apparatus anywhere near the required 10 times per day. The litter as a whole showed the same type of sensitiveness and fear as shown by the father. There were variations: e. g., one was markedly less sensitive than the others, making as many as 9 trials on the sixteenth day; and one was markedly more full of fear, after 40 days still refusing to go through the apparatus at all.

In comparison with these results the behavior of another litter (five pups of the same age), trained at the same time, from a different mother and the same father as the first litter trained (ex Psych by Engadin), serves as an excellent control. The dogs in this litter went through the apparatus at once, with none of the demonstrations of fear shown by the offspring of Prince at the movement of the doors or at the buzzers. In 6 days all but one of this litter were making 10 trials a day. The one exception acquired a fear complex after 2 days in connection with the side doors S_L and S_R. The dog would enter the apparatus freely and was not bothered by the buzzers or the movement of other doors, although the course of the trials was upset. This is quite different from the general fear shown by the offspring of Prince. The one surviving pup in a litter ex Psych by Prince, although not yet introduced to the association apparatus, shows strikingly certain peculiar characteristics of general behavior shown by the other pups from Prince.

It looks very strongly as though even in these very first experiments the inheritance of a dominant disposition or temperament is seen. This suggests the results of Davenport's study of periodic outbreaks of violent temper in man, which was shown to be a dominant trait. Temperament and the action of internally secreting glands are believed to be closely related, so that it is possible that the heritable material at the basis of this behavior in the dogs may be both glandular rather and nervous.

While the reactions just discussed are controlled mainly by temperament, the formation of the associations as measured by the proportion of correct turns is more of an index of intelligence. So far no very marked differences have appeared in this regard between the dogs trained; but as these have all been dachshunds, this does not preclude the appearance of marked differences when another breed is studied.

The behavior of dogs in the presence of other animals forms a rich field for the identification of characteristics of behavior. Individual differences between dogs in the same situation appear with clearness, but the evaluation of these differences, however obvious they may be, is a matter of considerable difficulty, and so far has not been successfully accomplished. Notes upon barking offer possibilities, since barking consists of a series of unit explosions that may be counted. Certain animals, when presented safely caged to the dogs, call forth constant barking, others no sound at all. Some dogs will always bark at certain animals, while others never bark at the same animals. Most characteristic of certain dogs are the intensities of the interest reactions, and these can be classified only in the most unsatisfactory and rough manner. There has been no difficulty in recognizing the extremes, even in the one breed; the same characteristics remain at different ages and appear under different circumstances. The dog that paid no attention to a mouse when a young pup, at a year shows no interest in mice, rats, or guinea-pigs; he fears the association apparatus. The bitch that most violently killed mice when a young pup, at a year fights furiously to catch any caged animal and has not the slightest fear of the association apparatus. All except one pup in the litter ex Cocoa by Prince showed fear at the presence of a guinea-pig in the kennel, and this was the one that soonest lost his fear of the association apparatus.

These general remarks will serve to show the lines along which further progress may be expected from the reactions of the dogs in the presence of other animals. They also serve to indicate that the differences observed are probably not due to mere irregularities of environment or experience, since they tend to persist and appear in various situations

Heredity of behavior in mice.—Two races of mice have been used for this investigation, which was carried on by Miss Emilia Vicari. They were a uniform race of Japanese waltzers that had been rendered very homozygous by over 100 generations of inbreeding, and a race of albinos continuously inbred since 1912 from the stock of Dr. H. Bagg, of the Memorial Hospital. This long history assured a purity that made this material of unusual value from a genetic standpoint. Miss Vicari reports:

> Of the two races, the Japs are deaf and have the waltzing habit, with characteristic agitated, nervous movements when not whirling around; they lack vigor and are small in size; they require care in regard to feeding and nesting, and are liable to gastro-intestinal disturbances. The albinos, on the other hand, hear. Not being waltzers, they are normal in their movements, and they are larger and more vigorous than the Japs; they are fully tame, with no fear of unusual noises or shadows. The immediate problem was to discover what racial differences in behavior might be demonstrated by their reactions in a simple maze, and then to trace such differences through the generations following the crossing of these races. The maze used (see fig. 4) consists of two successive compartments with right and left exit doors. To reach the food at the end of a trial the mouse has to take the left-hand door in the first compartment and the right-hand door in the second, the other doors being blocked with glass slides. To prevent the formation of scent trails, fresh paper was spread on the floor for each trial and all other precautions required in such experiments, such as uniformity of surroundings, of age, etc., were taken. The results are based on the number of perfect trials, the number of successive perfect trials, and the average time per trial. The following numbers of mice have been trained: 45 Japs, 75 albinos, 110 F_1 hybrids, and 40 in the second filial generation.
>
> The behavior of the parent races as measured by the reactions in this maze shows that the Japs and albinos are very similar when compared on the basis of the number of perfect trials and on the basis of the number of consecutive perfect trials; on the basis of time per trial the averages of the albinos tend to be lower than those of the Japs. So, in spite of the manifest differences between the races, it appears that their behavior in the maze is practically identical, although the Japs do not move as rapidly as the albinos. Turning to the F_1 hybrids, a surprising result is found: 10 per cent of the mice in this generation made more perfect trials than any parent in either parent race; some individuals excel all those in the parent races in the number of consecutive perfect trials; and the time averages, instead of being intermediate between those of the parent races, are considerably lower, lower even than the averages for the albinos. This last result is given when each family is considered by itself. The general behavior of these mice distinguished them unmistakably; they were hard to pick up because of their rapid, darting leaps, and scurrying to cover, like wild mice; they were responsive to every little sound, shadow, or motion. Obviously, like the albinos, they could hear, yet they were more sensitive. Physically they are sturdier than either

parent race and thrive well under all sorts of conditions, with any sort of food. It seems as though some phenomenon of heterosis is involved. Perhaps there has occurred a combination of factors that worked for greater vigor in the hybrids, and to this greater vigor is due the lowered time average. This same vigor probably does not account for the superiority in the number of perfect trials, for perfect trials are not closely correlated with time. This is shown by the pure races, which are alike in the matter of perfect trials, although the more vigorous albinos make better time.

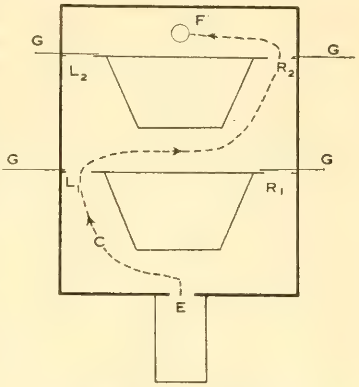


Fig. 4.—*Maze used for training mice.*—E indicates the entrance to the maze; R_1 and L_1 indicate right and left exits of the first compartment; R_2 and L_2 indicate right and left exits of the second compartment; G indicates glass slide used in closing pathway; F indicates food; C indicates correct pathway through maze.

Among the hybrids are not only those that make an unusually high number of perfect trials, but also a large percentage that make no perfect trials. When they once learn the way, the hybrids are more apt to make repeated perfect trials than either parent race, but they also are less apt to make a single perfect trial. This may be supposed to be due to the greater sensitiveness of the hybrids, appearing as fear; once this fear is overcome they show their greater ability to form and retain the habit.

Whatever interpretations may be made, the facts are clear that the mice of the first filial generation are neither intermediate between the parents nor like either parent. Rather do they show a greater capacity for learning accurately, when they learn at all, and on the average they take less time per trial. This demonstrates that the phenomenon of heterosis, so often shown in physical characters, may also be found in behavior. With the indications of the phenomenon of dominance in the dogs, and heterosis in the mice, as applied to traits of behavior, two steps towards the analysis of the genetic basis of behavior have been made.

Heredity in Sheep.

The experiments on heredity of twinning in sheep were continued. The triplet ram of last year was continued as the sire of the flock and the flock was fed heavily, even on grain, during September and October. But despite this precaution the average number of lambs per fertile ewe was 1.43, the lowest rate for many years. Also the stillbirth rate was exceptionally high, being 30 per cent of all lambs born. For next season's lambs a sturdy single lamb of twin stock is to be used.

GERMINAL AND SOMATIC VARIATIONS.

Studies on the Vascular Anatomy of Normal and Teratological Seedlings of Phaseolus vulgaris.

These investigations have been continued by Dr. Harris along lines indicated in previous reports (Year Book Carnegie Inst. Wash. 19:139). Harris, Sinnott, Pennypacker, and Durham have published the results for variation in the vascular structure of dimerous and trimerous plants (Amer. Jour. Bot., 7: 62–102, 1921). They find the structure of the trimerous seedlings fundamentally different from that of the dimerous seedlings, the former being on a plan of 6 instead of 4. But when a large number of seedlings is examined there is found a wide range of variation in the number and in the combinations of primary double bundles. The plants which are externally dimerous and trimerous are thus clearly differentiated in internal morphology; but these internal characters are transgressive. It is possible, though rare, to get a trimerous seedling (with 3 cotyledons) that has only 4 vascular bundles in the hypocotyl instead of 6. Papers on the correlation of the number of vascular elements in different regions of the seedling and on the vascular anatomy of hemitrimerous plants are now in press.

Direction of Whirling in Waltzing Mice.

Yerkes, in his work with Japanese waltzing mice, has noticed that these animals as a group are divisible into (*a*) those that made a vast preponderance of their turns in a right-handed or a clockwise direction, (*b*) those that made a great preponderance of their turns in a left-handed or counter-clockwise direction, and (*c*) those that were mixed, turning either to the right or to the left with approximately equal frequency.

In the Lambert strain of Japanese waltzers used by Dr. Little in this Department the same is also true. These mice are directly descended from a single pair of Dr. Yerkes's mice, isolated in 1906. They have been intensively inbred. It is therefore quite striking to note that there exist the three types of waltzers, none having been eliminated by inbreeding.

A study of the distribution of frequencies of clockwise-turns out of all-turns, based on hundreds of measurements, reveals a trimodal condition, proving that prevailingly clockwise and prevailingly anti-clockwise individuals are not merely the rare extremes of a variable series, but, on the contrary, constitute types as real as the mixed type.

It was also found that normal, non-waltzing mice, when recovering from anesthesia with ether, instead of progressing as they normally do in a straight line, ran or turned in circles. Although the proportions of the clockwise, counter-clockwise, and mixed types in this group differ from those in the Japanese group, there is evidence of the existence of the three types of reaction. In this experiment Dr. Little has had the assistance of Miss D. M. Newman as observer.

ALTERATION OF THE AVERAGE OF A POPULATION BY SOMATIC SELECTION.

Mechanical Devices for Analyzing Selection.

The study of mechanical contrivances which possess certain biological analogies was continued by Dr. Laughlin during the year. In the July 1921 number of Genetics there was published an article on

"Dice-casting and pedigree selection," in which it was shown that practically all of the mathematical and statistical phenomena of schemes of selection can be demonstrated by dice-casting. Specific examples were worked out in the case of regression, pure-line selection, and selection on the somatic basis.

SELECTION OF A PHYSIOLOGICAL CHARACTER IN CLADOCERA.

Dr. Banta's complete paper on this subject appeared as publication No. 305 of the Institution. Three species of Cladocera were used: two of the genus *Daphnia* and one *Simocephalus*. All were tested for their reactiveness to a constant light placed at one end of a long tank of water in which the Cladocera swam. All variations in reactiveness due to environmental conditions were considered and their effects, as far as possible, eliminated. For many generations the Cladocera that were the most responsive to light were selected and bred from to form the plus strain; the least responsive to light were similarly selected and bred from to form the minus strain. In most strains (13) the continued selection of more and less reactive individuals for generations did not cause the two lines to diverge in reactiveness. One strain (No. 757) showed a clear effect of selection. The lines diverged and the divergence was permanent (hereditary). The results indicate that selection alone was impotent to create diverging lines unless favorable mutations were occurring, and these apparently did occur in strain No. 757.

MODIFICATION OF A MENDELIAN RATIO BY SELECTION.

During the past year Dr. Little and Miss E. E. Jones have carried on an experiment with *Drosophila melanogaster* to determine whether or not the customary 1 : 1 Mendelian ratio in back-crosses of a single pair of characters can be modified by the isolation of different genetic strains incident with selection.

A pair of fourth-chromosome characters, normal-eyed and eyeless, was chosen. A control series showed that there was normally a slight deviation from the 1 : 1 ratio in back-crosses between normals carrying eyeless and eyeless flies. The observed ratio, which was 1.44 ± 0.02 normals to 1 eyeless, is the result of a differential viability of the sort frequently found in cases where a recessive mutation appears to be at a slight disadvantage when compared with the normal type.

Eight selection lines were started, two of which died too early to give conclusive results. Four lines were selected for an excess of normal-eyed and four for an excess of eyeless. The former are known as the high selection lines, the latter as the low selection lines. A detailed description of the experiment is almost ready for press.

STUDIES ON HUMAN GENETICS.

HEREDITY IN ARISTOGENIC FAMILIES.

Dr. Howard J. Banker has made a preliminary study on heredity of general intellectual ability as measured by collegiate standing. He reports as follows:

"The material consisted of the scholarship records of approximately 1,000 students of Harvard College, covering a period of 66 years. These individual records were selected primarily with reference to the relationship of father and son and incidentally also with reference to fraternal relationship. As the records covered a long period during which the methods of recording a student's scholarship standing had undergone great changes, it became necessary, for the purpose of comparison, to reduce the gradings to a uniform system. It was a question, therefore, whether from the original records themselves, or in the transformation of these records to a uniform system, there had been introduced such irregularities as to make the records incomparable.

"The first test was to plot a frequency distribution of the average grade of each student on a scale of 5 divided into tenths, making 40 classes, with 1 as the highest grade and 5 as the lowest. The distribution was determined, first, for the entire period of 66 years, also for three subperiods of 22 years each, and finally for two subperiods of 40 and 25 years respectively, the former covering the period of chiefly paternal grades and the latter the period of chiefly filial grades, the object being to compare these different periods for any marked variations.

"The resulting curves showed close approximation in one-third of the highest grades and in one-seventh of the lowest. In the intermediate one-half they diverged considerably, but in such uniform fashion as to indicate the operation of some fundamental law and not as the expression of any haphazard irregularity. Table 7 gives the principal constants for the curves for the three subperiods of 22 years.

"These results encouraged further statistical use of the data and a study was made of the correlation between fathers and children[1] as to their general averages in all subjects. Various methods were employed, as the object was chiefly to test the value of the data in statistical work. Table 8 furnishes an interesting comparison with a study made by Schuster and Elderton on Oxford students."[2]

TABLE 7.—*Constants of polygon of frequency of scholarship grades at Harvard College for the given periods. σ, Standard deviation.*

Period.	Mode.	Mean.	σ
1850–1871	3.9 ?	3.02 ±0.056	0.9365 ±0.0396
1872–1893	3.4	2.97 ± .031	.7438 ± .0218
1894–1915	3.0	2.83 ± .021	.6707 ± .0146

"The Oxford material, which included 2,459 sons, was classified by Schuster and Elderton into six groups according to standing at graduation, as follows: first, second, third, and fourth honors, passed, and no degree. The Harvard material, which included only 404 children, was grouped into four classes of equal grade intervals. These constituted the 'full table.' For the sake of comparison, r was computed for both the Oxford and Harvard tables on the assumption that the classes in each were of equal value. As a further test of the results, a correlation table of the Harvard data, called the 'expanded' table, was constructed on the grades divided to tenths. In all three cases r was computed by Pearson's 'product-moment' method.

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[1] A very few girls were included in the data.

[2] Schuster and Elderton. The inheritance of ability, being a statistical study of the Oxford class lists and the school lists of Harrow and Charterhouse. Eugenics Laboratory Memoirs, I. London, 1907.

TABLE 8.—*Coefficient of contingency and correlation in ability between fathers and children.*

Date.	Authority.	Full table.			Four-fold table.
		C_1	C_2	r	r
Oxford, 1860–1892.....	S. & E....	0.26	0.29	....	0.29
	B........	[1]0.256	[3]0.291	[2]0.226 ±0.013	[3]0.289
Harvard, 1850–1915....	B........	[1]0.307	[3]0.366	[2]0.247 ± .0315	[3]0.408
	B........	....	....	....	[4]0.398 ± .0027
Harvard expanded.....	B........	....	....	[2]0.302 ± .0304	[5]0.397

C_1 = mean square contingency coefficient.
C_2 = mean contingency coefficient.
r = coefficient of correlation or association.

[1] Pearson's "Theory of contingency." Drapers' Co. Research Mem.; Biom. Series I., Math. Contrib. to the Theory of Evolution XIII, 1904, as cited by Schuster and Elderton, *op. cit.*, 7.

[2] Pearson's "Product-moment" method, after West: Introduction to Math. Statistics, 83–84,

[3] Pearson's "Correlation of characters not quantitatively measurable," Phil. Trans. Royal Soc. of London, Series A. 195: 1–47, 1900, as cited by Schuster and Elderton, *op. cit.*, 7.

[4] By Yule's formula; Q (or r) $= \cos \frac{\sqrt{bc}}{\sqrt{ad}+\sqrt{bc}}\,\pi$.

[5] By "Method of unlike signs." Whipple, Manual of Mental and Physical Tests, 1:50, 3d ed., 1914.

"A further comparison of the percentage of children in different grades whose fathers were of first or second grade gave a difference in the parallelism of the fitted straight lines of the Harvard and Oxford data of only 4′ of arc, i. e., a divergence of about 1 mm. in 1.75 meters. Various other statistical values were computed which need not be discussed here.

"The conclusion drawn was that the data, on the whole, were sufficiently reliable to give significant indications. Although scholarship grades may be considered a crude measure of intellectual ability and far from ideal for scientific purposes, they are at present the best that we have covering a period of more than one generation. In view of the results obtained and the lack of any more reliable data, it seems very desirable to utilize such material in further investigations.

"One serious fault in both the Harvard and Oxford material as a basis for studies in heredity is the utter lack of data concerning the females. This is especially unfortunate as pertaining to consorts, since it deprives us of data as to the type of matings. Naturally, the suggestion was to secure the records of coeducational schools, but the fact that coeducation in this country is of very recent growth, as well as other considerations, discouraged the attempt to obtain these records. The result of the Harvard studies, however, stimulated the desire to see what might be available.

"Inquiries were addressed to some 280 coeducational institutions all over the United States, including about 200 colleges, as to the extent and character of their records. Replies were received from 184. Of these, 73 were at once rejected because of insufficient records, 70 appeared to give promise of material of some value, and 41 were uncertain. Several surprises appeared in these answers. First, that coeducation and the preservation of complete records often covered a longer period than was expected; second, that in a number of cases the schools were in a sense family institutions, having from 25 to 60 per cent of their present students the children of former students. One institution has a Second Generation Club; others have grandchildren of former students in attendance, and one claims "four or five generations." A number of coeducational colleges date back 50 to 70 years, and several have records complete from the beginning. High-grade secondary schools have even a longer coeducational record, one claiming over a hundred years, and several have preserved their records complete for more than 70 years.

"Eager to test the quality of this material, as soon as I was relieved of office duties I spent a month abstracting the records of one college. Though a small institution, having an annual registration of about 500, and the records dating only from 1872, I obtained the scholarship grades of both parents and from 1 to 5 children in 26 families. There has not been time to systematize this material and properly to compute the averages. A rough approximation was, however, made as a means of estimating the value of the data and table 9 compiled.

"The results shown by table 9 are too crudely computed to be worth serious discussion as bearing on facts of heredity, but they are of value as indicating that the original data in all probability possess significance and are of value for research purposes. A definite relation of some sort between type of children and type of parental mating seems evident.

"It is needless to call attention to the fact that the data from one such institution are manifestly inadequate to yield the most reliable results in statistical work. They encourage and emphasize, however, the need of securing additional material from other institutions. In spite of the criticism that may be passed as to the inaccuracy of scholarship records as a measure of intellectual ability, it seems quite evident that we have in these schools the most valuable data now in existence for the quantitative study of intellectual heredity, and there is no prospect for many years to come of any better material. It is to be hoped that opportunity and facilities for obtaining such records will be afforded."

TABLE 9.—*Distribution of intellectual ability in children of particular matings.*

Type of parental mating.	No. of families.	No. of children of each type.			Average grade.	
		L.	M.	H.	Parents.	Children.
L×L.........	2	3	3	......	73.1	73.5
L×M.........	1	......	1	......	75.6	76.2
L×H.........	2	......	6	......	79.0	80.5
M×M.......	5	4	6	1	80.9	77.4
M×H........	9	4	4	4	84.5	79.5
H×H.........	7	1	7	6	88.4	84.4
Total......	26	12	27	11	83.4	79.8

L = grades less than 75 per cent.
M = grades between 75 and 85 per cent inclusive.
H = grades more than 85 per cent.

HEREDITY IN CACOGENIC FAMILIES.

Dr. A. H. Estabrook has continued his researches on the "Ishmaelites" of the central States. His work this year has been mainly the finishing of the history of the families that had been previously studied and the compilation of hospital and other official and private records in Indianapolis and the counties where Ishmaels are found. In the latter work, which involved much travel, he was assisted by Miss Corinne S. Eddy, of Indianapolis. Dr. Estabrook's investigations were somewhat disturbed by the migrations that occurred during the recent war and which had an economic basis. He reports that his final report on the Tribe of Ishmael is approaching completion.

In collaboration with two workers from the State university, a mental survey was made of the children in two white orphans' homes in Indianapolis. Mental age determinations were made for each child over the age of 5; about 200 children were studied, some of these being Ishmaels. A brief report of this work was read at the December meeting of the Indiana Academy of Science and is being published in the proceedings, December 1920.

A few days were spent by Dr. Estabrook in visiting the Indiana Hospital for Insane Criminals and the Indiana Colony for the Feeble-minded at Butlerville to make a brief study of all the feeble-minded men convicted of crime in these institutions, for the purpose, with what family history was available, of making recommendations as to whether or not these men should be placed in colony care as feeble-minded. This was done at the request of the Committee on Mental Defectives.

Since December 1920, on each Monday morning of the past year, at 11 a. m., a conference has been held in Indianapolis of representatives of all social agencies dealing with mental cases. Mental cases have been presented by such agencies for discussion and suggestions for treatment and follow-up work. Dr. Estabrook served as chairman here because of his knowledge of the State, its institutions, and its laws concerning the defective classes. This conference has been of value to him in his researches.

At each meeting of the Indiana Committee on Mental Defectives, Dr. Estabrook has been asked to meet with them in the consideration of their problems, and has done so.

INHERITANCE OF A TENDENCY TO "CANCER" IN MAN.

The question as to the inheritance of a tendency to the formation of malignant tumors has long been an open one. Medical men have held divided opinions, and statisticians have reached contradictory or inconclusive results. The work of Murray, Tyzzer, and Slye appears to have established independently the *fact* of inheritance of a tendency or tendencies to "cancer" formation in mice. The *method* of inheritance of such tendencies is still largely a matter of conjecture and needs further research before definite conclusions can be drawn.

A bulletin of this Office has shown a strong familial tendency to the formation of multiple neurofibromatoses, and it is naturally of great interest to attempt an analysis of the available material on the more malignant forms of the neoplasms in humans, to determine if possible whether or not they show the influence of heredity.

For this purpose the very numerous family histories at the Eugenics Record Office have been studied, and a careful tabulation of families *showing cancer* has been made by Dr. Little, with the help of Miss Charlotte Gower, Miss C. W. Gilman, and Miss D. M. Newman. As a control, the table given by Hoffman (Mortality from cancer throughout the world) on the number of deaths from cancer per 100,000 inhabitants in the United States Registration Area (1903–1912) has been used. These data are divided by sex and age groups as shown in table 10, from which the chance that any individual will die of "cancer" can be directly calculated. In our tabulation (table 11) individuals still alive have all been recorded as negative and have been given their individual values according to their respective age-groups and their sex. They represent unfulfilled chances for the production of cancer. In addition, the deaths from causes other than "cancer" have been added, thus deliberately increasing greatly the difficulty of demonstrating an heredity influence.

TABLE 10.—*Absolute number and rate per 100,000 of population of deaths from cancer at each age and for each sex.*

(From F. L. Hoffman.)

Ages at death.	Males.		Females.	
	Deaths from cancer.	Rate per 100,000 population.	Deaths from cancer.	Rate per 100,000 population.
Under 10	1,170	2.5	984	2.2
10 to 24	2,028	3.1	1,844	2.8
25 to 34	3,757	9.0	7,891	20.6
35 to 44	10,750	32.3	26,779	89.0
45 to 54	24,431	105.4	46,669	222.9
55 to 64	35,327	257.4	50,393	386.4
65 to 74	33,745	452.8	43,010	565.7
75 and over	18,381	620.2	24,601	734.1

The first group (A) to be considered is composed of fraternities whose father was cancerous and whose mother was normal.

In each sex and the total the excess of cancerous individuals among he progeny of cancerous fathers and normal mothers is striking.

TABLE 11.

Groups.	Sex.	Total non-cancerous.	Total cancerous.	Cancerous individuals expected.	Excess of observed over expected.	Odds against excess being due to chance alone.
A. Children of mating, father cancerous, mother non-cancerous	Males	939	14 ±2.50	0.85	13.15	More than 1,350 to 1.
	Females	778	10 ±2.12	1.05	8.95	215 to 1.
Total		1,717	24 ±3.27	1.90	22.10	More than 100,000 to 1.
B. Children of mating, father non-cancerous, mother cancerous	Males	553	12 ±2.33	1.19	10.81	520 to 1.
	Females	477	27 ±3.40	1.59	25.41	Over 500,000 to 1.
Total		1,030	39 ±4.13	2.78	36.22	Over 1,500,000 to 1.
C. Sibs of a cancerous individual		2,016	48 ±4.61	5.80	42.20	Far over 1,500,000 to 1.

A similar result is observed in group B, in which a tabulation of the immediate progeny of cancerous mothers and non-cancerous fathers is made.

Finally in group C is included fraternities in which at least one cancerous individual appears. If chance alone is operative, there is no reason why the sibs of such cancerous individuals should be cancerous any more frequently than is the population at large. Actually, however, a great excess is obtained.

From the above three lines of evidence we may conclude that *there exist in man one or more heredity tendencies to the formation of malignant neoplasms.* Further, we may state that in so far as present evidence is concerned *the method of inheritance follows no simple Mendelian behavior.* This does not preclude the possibility that Mendelian inheritance involving multiple factors and the action of modifiers will be found to apply when more suitable material is available for analysis.

MUSICAL FAMILIES.

Miss Hazel M. Stanton made a quantitative study of inheritance of specific musical capacities during the winter of 1919–20. She measured as many as possible of the members of 6 family groups having one or more musical members, with respect to sense of pitch, sense of intensity, sense of time, and tonal memory, all made quantitatively by the method elaborated by Professor C. E. Seashore, of the State University of Iowa. She obtained also supplementary descriptive data on a number of matters relating to their musical environment and history. The results will appear both in the "Studies" of the University of Iowa and the Bulletin of the Eugenics Record Office. The original pedigree charts and copies of all records are deposited at the Office. Altogether, 85 persons were measured by the Seashore tests, and data were obtained concerning 446 other persons. Miss Stanton concludes that the four factors studied are inherited independently. As a first approximation, the evidence suggests that superior capacity dominates over average and poor capacities, rather than the reverse. The study is perhaps the first quantitative study of the inheritance of a special capacity.

Calculating Ancestral Influence.

Studies on formulæ for calculating ancestral influence have been continued by Dr. Laughlin. A more complete statement (than that which appeared in the Proceedings of the National Academy of Sciences for May 1920) of formulæ and their explanations was published in Genetics for September 1920. To the 24 original formulæ, which measure specific contributions of ancestral chromosomes, one more rule of pedigree analysis was added. This rule is: In a species in which the female sex-chromosome formula is $X+X$, the minimum number of ancestors in a given ancestral generation, among whom will be found all of the possible contributors of the sex-chromosomes to the F_1 *female* zygote, is equal to the Fibonacci serial term $p+3$, in which p is the number of the given ancestral generation (for parents $p=1$, for grandparents $p=2$, etc.). In a species in which the sex-chromosome formula for the male is $X+Y$, the minimum number of ancestors in a given ancestral generation, among whom will be found all of the possible contributors of the sex-chromosomes to the F_1 *male* zygote, is equal to Fibonacci term $(p+2)+1$.

Eugenics in Germany.

An analysis was made by Dr. Laughlin of the Constitution of the new German Republic, in which it was found that many provisions were made by the German people for the maintenance of racial vigor and fecundity of the German stock. A short account of this study appeared in the Eugenics Review for January 1921.

STUDIES ON THE RACIAL CONSTITUTION OF AMERICAN POPULATION.

Army Anthropology.

The Director was requested by the Surgeon General of the Army, on July 7, 1919, to supervise the measurement of 100,000 soldiers at demobilization. It was directed that white and colored should be distinguished, also the nationality of those born abroad or of parents born abroad. The Director spent part time in Washington for about 3 months in the summer and autumn of 1919 and supervised the tabulation of the results and wrote the text of the report during 1920. The completed report was issued from the Government Printing Office in December 1920.

The report comprises 635 pages. It discusses stature, weight, chest circumference, and build for 1,000,000 draft recruits and 19 other measures for 100,000 veterans. The report indicates that the average stature of the population of the United States has diminished about half an inch during the past 50 years (doubtless due to excess immigration of short races); that men from Texas were the tallest and those from Connecticut shortest; that of any "section" the "Southern highlanders" are the tallest, and next the men of the Ozark mountains; while Rhode Island and the eastern manufacturing cities contain expremely short people, each due to the racial stock formed there. The average stature of negroes was practically the same as of whites.

Weight proved to be greatest in Alaska and the northern tier of States; the French Canadian sections showed the least average weight. In chest circumference the tall Southerners of Scotch origin were least, and the stocky Finns and agricultural Russians greatest. In general, the Nordic races in America have relatively longer legs and shorter trunks than the Mediterraneans. The Nordics have broad, shallow chests; the Mediterraneans narrow but deep chests. The negroes, of the same average stature as whites, have longer arms, longer legs, narrower pelvis, higher thoracic index (relatively broader chest), larger, shorter necks, and greater weight than the whites. Variability of dimensions was calculated for all races, and correlation of parts. Eye and skin pigmentation deepens from the northern tier of states to the Gulf of Mexico.

Physical dimensions were studied in relation to disease. Tall men are especially prone to have varicose veins, variocele, pulmonary tuberculosis, cardiac disorders, and goiter, both simple and exophthalmic. Short men have especially high incidence of defective teeth and refractive errors of the eye (characteristics of short races). Heavy men have an excess of varicose veins and flat feet; men of light weight have an excess of tuberculosis and heart disease. Chest circumference is large in men with asthma. High variability in any group results when it combines two or more dissimilar classes, e. g., the short racial group of myopics (largely Russian Jews) and others of average stature; chest circumference of asthmatics who are far advanced in the disease and those who are not. Where size and defect are intimately bound together as cause and effect, variability is low. Weight and lung tuberculosis, weight and mitral stinosis, varicose veins and stature are thus connected. Thus variability of a group of dimensions associated with a disease is inversely related to their interdependence as cause and effect.

IMMIGRATION.

On April 16–17, 1920, Dr. H. H. Laughlin made a statement before the Committee on Immigration and Naturalization of the House of Representatives, which was printed by the Government Printing Office during the current year, under the title, "The biological aspects of immigration." As a result of the evidence presented at this hearing, this committee desired further first-hand analytical studies along the same line. In order to secure the desired facts, the Committee on Immigration and Naturalization and the Assistant Director of the Eugenics Record Office are conducting a cooperative study which has for its purpose the determination of the extent and specific type of social inadequacy among foreign-born and native stock found in the several State and Federal institutions. Also, the same correlations between race and specific defect will be determined in stock descended from recent immigrants and from immigrants of more remote years. For the purpose of this study, institutions for the socially inadequate are grouped as follows: (1) the feeble-minded (including the mentally backward); (2) the insane (including the psychopathic and neurotic); (3) the criminalistic (including the delinquent and wayward); (4) the epileptic; (5) the inebriate (including drug habitués); (6) the diseased (including the tuberculous, syphilitic, and leprous); (7) the blind (including those with greatly impaired vision); (8) the deaf (including those with greatly impaired hearing); (9) the deformed (including ruptured and crippled); and (10) the dependent (including orphans, soldiers, and old folks in "homes").

At the present time there are 720 such institutions in the United States. The study is well under way. Preliminary reports have been received from 370 institutions in 48 States, and pledges of cooperation have been received from many more. If all goes well, this study should be completed before July 1, 1922. It is expected that an analysis of these data will measure, more accurately than has been done heretofore, the relative stabilities and specific inborn social values and handicaps of recent immigrants of various nationalities compared with the older American stocks.

An examination of the preliminary data supplied by the first 370 institutions which responded to the requests for data gave the nativity ratios as shown in table 12.

THE SOCIALLY INADEQUATE.

A survey of actual State administrative and institutional practice and needs in reference to the classifications of the socially inadequate classes has been made by Dr. Laughlin and published in the American Journal of Sociology for July 1921. It was found that a systematic classification of the socially inadequate classes is as necessary in the scientific study of society as the scheme of classification usually followed

TABLE 12.—*Nativity ratios in the population (1910) and in institutions.*

	Total population of United States, 1910.	In 81 State institutions, Jan. 1, 1921.	Ratio institution quotas to institution findings.
	p. ct.	*p. ct.*	
1. Native, both parents native	64.47	56.50	100 : 87.63
2. Native, one parent native-born, one parent foreign-born	6.60	8.23	100 : 124.69
3. Native, both parents foreign-born	14.23	15.29	100 : 107.44
Total native born (1, 2, and 3)	85.30	80.04	100 : 93.83
4. Foreign-born	14.70	19.90	100 : 135.37
Total foreign stock (2, 3, and 4)	35.53	43.49	100 : 122.40

is convenient in botany and zoology. It was found also that the older schemes of classifying human handicap are being discarded, and that as yet no new satisfactory systems have been evolved. The study of this problem is being continued.

RACE MIXTURE.

First-hand pedigree studies were made by Dr. Laughlin of the family distribution of personal traits in a Hawaiian-Chinese-Irish family of California. The traits considered were business thrift versus thriftlessness, musical sense versus lack of musical appreciation, love of the sea versus its lack, sound judgment versus its lack, quick temper versus emotional control, enthusiasm versus its lack. It was found that these traits (many of them racial) segregated and recombined in a quite clean-cut manner.

PHYSIOLOGY OF REPRODUCTION AND DEVELOPMENT.

INFLUENCE OF ENDOCRINE GLANDS OF MOTHER ON VARIABILITY OF OFFSPRING IN BIRDS.

Results obtained by Dr. Oscar Riddle during the present year demonstrate in a striking manner the indispensable need for the association of studies on the physiology of reproduction with investigations in genetics. First among these results is the discovery, made in collaboration with Mr. Embree R. Rose, of the physiological basis of a series of reproductive abnormalities involving the early elimination by death of numerous bird embryos. It has been definitely shown that at least many of these reproductive abnormalities and embryonic deaths are due to temporary or permanent insufficiency of the endocrine glands, particularly the thymus and parathyroids. Or, stated in terms more accurately descriptive of the present state of this investigation, the administration per os of the desiccated tissue of these glands, either alone or in combination, is specific for the restoration to normal functioning of most of these birds which produce egg abnormalities and embryos characterized by early deaths. Further investigation of this general problem is in progress.

A comprehensive study of the possible relation of nutritional deficiency to the above-mentioned reproductive abnormalities and embryonic deaths has been nearly completed during the year. The results lead to two conclusions of importance: (*a*) Few, if any, of the reproductive abnormalities and embryonic deaths referred to above are caused by insufficiency of vitamines A, B, or C; nor are they caused by lack of Ca, K, P, Na, Cl, S, Fe, Mn, As, or Si; nor by a deficiency of a long series of amino acids. These results, together with additional negative tests made with other glandular tissue and the positive results obtained with thymus and parathyroids, permit the conclusion concerning the specific deficiency of the two last-named organs. (*b*) This practical demonstration of the freedom of our present material from nutritional deficiency, at the only time such deficiency has been suspected, affords ample and most desirable evidence that in our earlier prolonged quantitative study of one or another aspect of the metabolism of these doves there has been little or no complication of the results traceable to nutritional deficiency.

Transplantation of Adrenals and Gonads into Doves.

Dr. Riddle is making, in collaboration with Dr. Tadachika Minoura, a guest of the Department, a study of the possibilities and effects of repeated adrenal transplantation upon young and maturing ring-doves. Certain associations of the adrenals and the gonads make it desirable to learn as much as possible of the special relations which may exist between these as well as other endocrine glands on the one hand and the various aspects of sex-development and of reproduction on the other.

Dr. Minoura has utilized a specially suitable part of our material during much of the past year for the transplantation of testis or ovary upon the growing embryo or upon the very young dove. It has been found advisable to rear most of these operated embryos and young to or beyond the period of maturity.

In addition to the studies noted above, Dr. Minoura is utilizing a group of birds in our collection, and a part of the weight records earlier obtained by Dr. Riddle, for the construction of the normal growth-curve of the ring-dove. In this connection he is particularly seeking to identify the exact time of the rather sudden enlargement of the gonads (which occurs at maturity in the dove) with a definite and unusual feature of the dove's growth-curve.

The Origin and Interpretation of One-Yolk Twins in Doves.

Dr. Riddle has long been looking for one-yolk twins in pigeons, since the material is highly advantageous for the study of this phenomenon, for the embryo is accessible throughout the period of its embryonic development, and, because of the transparency of the shell, twins can be early and definitely identified. Moreover, when the egg-weights have been carefully kept, the prospective sex of the embryo is often known. It appears that one-yolk twins, of the female sex at least, can develop fully within the eggs. The chief difficulty in the study is the rarity of this form of twinning; only 7 cases have occurred in from 15,000 to 25,000 eggs examined. Of these seven, 2 produced in 1915 and 1916 have been already described. This year 2 new cases have been found; and the occasion is taken to give data concerning all 7 cases in table 13.

TABLE 13.—*Summary indicating the abnormal size of 7 eggs from which arose 7 pairs of identical twins and the origin of female twins from ova of largest size.*

The weights of twin-bearing eggs are set in Italic type.

No. of female parent.	Clutch.	Data on eggs of twin-bearing clutch.				Average weight of 5 eggs laid by same female immediately:[1]		Maximum and minimum weights for other than twin-bearing eggs (same year).		
		Date.	Weight (grams).	Per cent of diff.	Sex (or stage).	Before.	After.	Max.	Mini.	Total.
A248	K1	Apr. 7	7.43	....	♂	7.62	8.11	8.22	7.10	23
	K2	Apr. 9	*10.63*	+43.1	♀ ♀	8.75	8.92	9.17	8.46	22
60	F1	Mar. 5	8.07	....	♂	8.21	7.58	8.68	6.72	22
	F2	Mar. 7	*10.08*	+24.9	♀ ♀	8.13	7.84	8.65	6.15	21
V49[2]	D1	Oct. 16	[2]15.77	....	♂	14.80	17.05	17.40	14.80	8
	D2	Oct. 18	*20.60*	+30.6	♀ ♀	15.33	18.06	18.23	15.33	7
P450	D1	May 30	8.92	....	♂	8.76	9.02	9.21	7.82	17
	D2	June 1	*10.39*	+16.5	4 to 5 d.	8.90	9.17	9.75	8.12	14
K465	E1	Mar. 4	8.00	....	1 to 2 d.	7.59	7.95	8.87	6.87	17
	E2	Mar. 6	*8.05*	+ 0.6	2.5 d.	8.24	8.50	9.29	7.82	13
K465	K	May 14	*8.47*	....	4.5 d.	7.95	8.18	8.87	6.87	17
						8.50	8.64	9.29	7.82	13
P843	C1	Mar. 15	*6.40*	− 3.7	3.0 d.	7.51	7.04	....	....	2
	C2	Mar. 17	6.64	....	2.0 d.	7.10	6.90	....	....	3

[1] The upper number in each pair below is the average of 5 *first* eggs of the clutch, the lower number of 5 *second* eggs.

[2] Common pigeon; all other groups are ring-doves.

An inspection of table 13 shows that in the case of the first 4, the twin-producing eggs were distinctly larger than *any* other eggs produced by the prospective parent during the year. In all cases (3) where the twins developed to an age at which sex could be determined the sex was female. Dr. Riddle points out that the large size of these female twin-producing eggs harmonizes, in so far, with his earlier observations that females arise from eggs (yolks) of high storage metabolism, hence large eggs. It is noteworthy, also, that the small eggs that produced twins died; possibly because of inability of small yolks to meet the needs of twin embryos.

THE PREDICTION OF FUTURE EGG PRODUCTION IN THE FOWL FROM ITS FECUNDITY AT A PARTICULAR TIME.

With the development of more intensive agriculture and animal husbandry, there must be an increasing stringency of selection of the individual organisms upon which production depends. For the past several years Dr. Harris, with a number of collaborators, has been working on the problem of the prediction of the future egg-production of the fowl. It is upon the possibility of such prediction that the elimination of poorer birds from the flock, with a consequent increase in average production, depends. In a memoir recently published (Genetics, 6 : 265–309, 1920) he has shown that for a flock as a whole the average annual egg-record may be predicted with a relatively high degree of accuracy from the egg-production of any individual month. These studies pertain to the records of White Leghorn birds, trap-nested for a period of 7 years at the Storrs International Egg-Laying Contest. Studies on White Leghorn birds at other localities, as well as the fundamental biometric determinations on other breeds, are now under way.

The foregoing investigations have been limited to first-year production. The opportunity for an investigation of the relationship between first and second year production is presented by the splendid records of the Vineland Internationl Egg-Laying and Breeding Contest. Dr. Harris is analyzing these data in cooperation with Professor H. R. Lewis, of the New Jersey Agricultural Experiment Station. The results so far obtained show that, contrary to the statements of some of the earlier students of poultry genetics, there is a material degree of correlation between the records of the first and the second laying year. Thus, it is possible to extend the practice of culling to the betterment of second-year production. The results show, furthermore, that in the White Leghorn the highest correlation between the yields of individual months are not found in the months of the so-called "winter cycle," but in the autumn months. This is contrary to what would be expected if high annual egg-production were due primarily to a superimposed Mendelian factor for high winter production. A detailed account of a portion of this work is now in press.

EFFECT OF ALCOHOL ON THE FERTILITY AND GROWTH OF RATS.

Fertility.—In the course of Dr. MacDowell's work with rats and alcohol, data upon fertility and growth have been accumulated. From year to year references have been made to this material as it was being collected (Year Book 1917, p. 116; 1918, p. 113). During the present year all the data on these subjects have been analyzed and the results have been presented in two papers: "The influence of alcohol on the fertility of white rats" and "Alcohol and the growth of white rats" (to appear in Genetics). Dr. MacDowell reports on his results as follows:

"The data on fertility include: (1) the numbers of rats per litter; (2) the numbers of litters produced by the tests and controls in the same time. The summaries are based on 177 pairs of rats, which produced in all 1,755 offspring. In all the experiments dealing with alcoholism, this is probably the first time that the fertility of treated animals has been tested by comparisons with full brother and sister controls. The first series of experiments, those with the light dosage, shows an average reduction of 11.5 per cent in the size of the litters produced by the treated females by treated males, as compared with the average litter-size of the controls; in the second series of experiments, those given the maximum dosage, the corresponding difference is about the same, namely, a reduction of 10 per cent in the size of the litters produced by the treated parents. The treated children of the treated rats produced litters that were 10.3 per cent smaller than the corresponding controls. So it appears that treating the parents as well as the rats themselves does not intensify the reduction in the size of the litters produced. The untreated children of treated parents produced litters that were 11.2 per cent smaller than the controls, and the untreated grandchildren from untreated parents and treated grandparents produced litters that averaged 13.1 per cent smaller than the controls. Although these differences in each generation by itself are not based on large enough numbers to make them statistically significant, when the litters in all the generations are taken together, the probable error is reduced so that the difference is fully significant (3.6 times its probable error).

"Given equal time, the treated rats produced 0.72 litter per pair, while the controls produced 2.07 litters per pair. This is a reduction of 64.86 per cent ± 3.37 in the number of litters, and, as it is 19.2 times its probable error, it is significant beyond all question. The first litters produced by the treated rats were slower in appearing than the controls, although the treated and control pairs were mated at the same age. So, besides giving fewer litters, the treated pairs were slower in producing the litters that were born. Turning to the numbers of litters produced in the later generations, the treated rats from treated parents also produced fewer litters than the controls, but instead of a greater reduction than in the previous generation, this second treated generation produced relatively more litters. The reduction was 35.45 per cent ± 6.91 of the controls. Coming to the rats not directly treated, untreated rats from treated parents gave 33.30 per cent ± 8.20 *more* litters than their controls, and the untreated rats from untreated parents and treated grandparents produced 55.60 per cent ± 8.40 *more* litters than the controls in the same generation. All of these differences are fully significant.

"From the above statements, it is clear that the factors that condition the size of litters are not identical with those for the numbers of litters. The effect of alcohol upon the size of litters in all generations studied is relatively constant, whether the parents themselves were treated or only the grandparents, or great-grandparents; but the *number* of litters is strongly reduced when the parents themselves are treated, though when the alcohol is more remote the reduction vanishes; the later descendants of the treated rats produce more litters than the controls. To explain the reduction in the number of litters in the presence of alcohol along purely physiological lines would be a simple matter, but a genetic explanation is required when it comes to the increase over the controls in the numbers of litters produced by the untreated descendants of the alcoholized animals. It seems necessary to assume that there are genetic factors influencing the number of litters that are produced; the alcohol prevents the reproduction of such females as carry, genetically, a lower reproductive capacity, so that the litters produced come alone from females carrying higher litter-producing capacity and they in turn produce larger numbers of litters than the unselected controls. When these offspring of treated rats were themselves treated, they produced fewer instead of more litters than the controls, but the genetic superiority is shown by the fact that the alcohol reduced the numbers of their litters by only 35 per cent, while it reduced the numbers in the earlier, unselected generation by 65 per cent. This selective action of the alcohol will account for the results from the number of litters, but not those from litter-size; if this is correct, it indicates that the number of litters is influenced by genetic factors that do not influence litter-size. This is not difficult to believe, since litter-size is largely dependent upon the number and constitution of the germ-cells, while the somatic conditions of the parents play a large part in determining whether or not a litter will be produced. This distinction between the effects upon the numbers of litters and upon their size has not been made by previous investigators. The results from litter-size agree strikingly with those of Stockard from similar studies with guinea-pigs; the results from numbers of litters agree with Pearl's on fowl in so far as both results demand the assumption of a selective action of alcohol. In the fowl the alcohol appears to select between germ-cells, in the rats it appears to select between females.

"*Weight.*—The weight data form an extensive series, consisting of weekly weighings of practically all the rats raised in the various generations in the second series of experiments (those with the heavy dosage, started in 1916). The weights used in the summaries were read from the individual growth-curves at certain ages. This procedure was necessary, since the weighings for all rats were made on the same day each week, when the rats naturally were of different ages. The results are based primarily on the males, since the pregnancies of the females make their data less reliable. In the summaries, the pregnancies have been arbitrarily smoothed out. Each of the four strains shows that treated rats tend to grow more slowly than the controls. This is an influence felt by the population as a whole, although there are some males that remain as heavy as the heaviest controls. The females show a similar retardation in growth, but this is not so marked as in the males. The offspring of the treated rats tend to grow *more* rapidly than the controls. This result is not so clear as the opposite result in the preceding generation; the differences are not so large and all strains do not show this in equal measure. In comparison with the results from the numbers of litters this shows a marked similarity, which is further borne out by the results from treated rats from treated parents. Instead of causing still further reduction in weight, the treatment of the offspring that came from treated parents appears to leave the animals about equal to the controls. Just as upon the numbers of litters alcohol works as a selective agent eliminating the litters that bear the genetic determiners for slower growth, so the offspring from treated parents grow faster than the controls, and when they themselves are treated the reducing effect of the alcohol makes them about equal the controls instead of growing markedly slower, as did their parents. Very little can be concluded from the weights of the grandchildren of treated animals. The numbers are too small to determine whether or not the expected continued superiority of the tests is realized. Two of the strains show the tests heavier and one of them shows the tests lighter, but the averages for all strains together show the averages for the tests heavier at all points."

INTERNAL MIGRATION OF OVA IN RELATION TO MULTIPLE BIRTHS.

In connection with the problem of plural births in man, Dr. George W. Corner investigated at Cold Spring Harbor during the summer of 1920 the problem of lost embryos in swine. As a first step he was able to demonstrate that practically all of the ova that have recently been ovulated can be recovered from the Fallopian tubes and agree in number with the corpora lutea of the ovary next to the tube. There has been no external migration, e. g., from the right ovary into the fimbriated end of the left tube. At later stages a migration occurs in the horns of the uterus such that an approximately equal number of embryos comes to develop in each side.

OTHER INVESTIGATIONS.

TUBERCULAR INFECTION OF PIGEONS IN THE SEXES AND IN HYBRIDS.

Several years ago Dr. Riddle noted that either advanced tuberculosis in some of the organs of the pigeon, or the presence in quantity of the worm *Ascaridia maculosa* Rudolphi in the pigeon intestine, is capable of preventing the growth of the testis; and, further, if the testis has first attained its full size, the later occurrence of either of these conditions will cause its nearly complete atrophy. Dr. Riddle now reports:

"Since the size of the two gonads in relation to one another was early found to be of some importance in the comprehensive study of sex in pigeons now in progress, we have made rather careful necropsies upon practically all the birds that have died of disease or have been killed in presumably healthy state during the past 10 years. During the last 7 years of this period the data thus obtained for tuberculosis was so recorded as to indicate not only the frequency of infection in the various organs, but the relative extent or degree to which the organs of the body (exclusive of head and neck) were invaded by tubercles. The data of this 7-year period have recently been summarized and are now in process of publication. The following conclusions are drawn from the study:

"Statistical data are given for the relative extent to which the various organs of 940 Columbidæ were infected with tuberculosis or with a macroscopically similar infection. Bacteriological examinations of these infections were not made, but there can be little doubt that most of these were cases of infection by avian tuberculosis bacilli.

"Four of the five groups examined show the spleen, liver, and lungs infected in this relative order; the spleen and liver alone include about two-thirds of the total number of the obviously infected organs of the body.

"The common pigeons present a similar yet appreciably different ranking of infected organs, since the relative order for this group is: liver, spleen, joints, and lungs.

"The organs most often infected are apparently also the most intensively or extensively infected organs.

"It is suggested that since the order of infection of organs in common pigeons is essentially the same as the order in which the organs of these birds remove intravenously injected bacteria, as shown by Kyes, there is some sort of causal connection between the two facts.

"Results recently obtained by other investigators on the distribution of injected manganese dioxide in the fowl also seem to invite the suggestion that, in pigeons, the organs which probably remove most of such finely divided non-living particles and most infecting bacteria from the blood-stream are the organs most often infected by tuberculosis.

"The ovary is probably more often infected than is the testis in most groups of pigeons; in domestic or common pigeons the data indicate an equal susceptibility of ovary and testis to this infection.

"The organs of hybrid birds derived from different genera are probably not changed in their relative susceptibility to tubercular infection by the mere fact that these organs are of hybrid origin.

"In addition to a possible contribution to our information concerning the localization of the attack of the tuberculosis bacillus, and also to our conception of phagocytosis, two points of more immediate relation to my own field are indicated by this study. First, the probability that the ovary is more susceptible than the testis to tuberculous infection in pigeons other than common pigeons, but equally susceptible in the latter forms, may prove to be of significance in the theory of sex. Second, the present incomplete story of the effects of hybridization is perhaps none the more incomplete because of the observation that the organs of hybrid birds derived from different genera are probably not changed in their relative susceptibility to tubercular infection by the mere fact that these organs are of hybrid origin."

Studies on Physico-Chemical Properties of Vegetable Saps.

The problem of the adjustment of parasitic plants to the conditions presented by the host.—Dr. Harris has continued the investigations on the evolution of loranthaceous parasites, which have been under way for the past several years. Harris and Valentine have shown (Proc. Soc. Exp. Biol. Med., 18 : 95–97) that the specific electrical conductivity of the tissue fluids of the parasite are higher than those of the host. Harris, Lawrence, Hoffman, Valentine, and Mrs. Lawrence are now engaged on further studies of the electrical conductivity and hydrogen-ion concentration of the tissue fluids of *Phoradendron* and its hosts in the Gila River Valley, Arizona.

Physico-chemical properties of the tissue fluids of alpine and subalpine vegetation.—Through the courtesy of Professor F. E. Clements, Associate in Ecology of the Carnegie Institution of Washington, it has been possible for Dr. Harris to extend the work on the physico-chemical properties of plant-tissue fluids in relation to environmental factors and geographic distribution to include the alpine and subalpine vegetation of the Pike's Peak region of Colorado. Mr. and Mrs. John V. Lawrence devoted some weeks to measurements of osmotic concentration, specific electrical conductivity, and hydrogen-ion concentration at Professor Clement's Alpine laboratory during the summer of 1921.

Physico-chemical properties of coastal vegetation.—For the past several years studies of the sap properties of coastal vegetation in their relation to the adjustment of the species to various salinities have been under way. Extensive series of determinations have been made in the neighborhood of Cold Spring Harbor (Long Island), Miami (Florida), and on the eastern coast of the Gulf of Mexico. In 1917 work by boat was carried out from Miami to Fernandina, Florida. In 1919, Dr. Harris, accompanied by Mr. John V. Lawrence and Mr. M. C. E. Hanke, covered the territory between Norfolk, Virginia, and Miami, Florida. In 1921, one month was devoted to work, on a small yacht placed at Dr. Harris's disposal by a friend, on the vegetation between Charleston, South Carolina, and Miami, Florida. Messrs. A. T. Valentine and C. W. Crane assisted in these field operations, in which particular attention has been given to the changes in typical halophytes as they extend up the fresh-water courses, and to typical fresh-water species as they reach the limits of their distribution seaward. Reports on the results are waiting the completion of analyses.

These investigations have been facilitated by the cooperation of the Department of Botanical Research.

Studies on the physico-chemical properties of the tissue fluids of cereals under irrigation and under dry-farm conditions.—Work on the changes in the properties of the tissue fluids of the small grains during the march of the season, carried out by Dr. Harris incidental to studies on the native vegetation of the Bonneville Basin in 1920 (Year Book, Carnegie Inst. Wash., 1920, p. 143), indicated the desirability of more detailed studies. These were made possible by cooperative operations with the United States Department of Agriculture and the Utah Agricultural Experiment Station in 1921. Mr. W. F. Hoffman and Mr. A. T. Valentine, field assistants, went to Utah early in June to take up these studies, and Dr. Harris went to the field July 1. The problem is essentially one of the capacity of the organism for adjustment to environmental changes. Through the kindness of Professor George Stewart and Mr. A. D. Allen, of the Utah Agricultural Experiment Station, it was possible to institute comparisons between irrigated and dry-farm cereals. The problems under consideration are:

1. Comparison of capacity for change in osmotic concentrations in different cereal species in relation to the problem of survival and productiveness under desert conditions.
2. Comparison between different varieties within the same species to determine whether growth and yield under desert conditions are related to sap properties.

STATISTICAL THEORY OF PLOT TESTS.

These investigations have been continued along lines indicated in previous Year Books by Dr. Harris. An exhaustive study of the permanence of differences between the plots of an experimental field has been published by Harris and Scofield (Jour. Agr. Res., 20 : 335–356, 1920), who have treated the data of 9 years' continuous cropping at the Huntley, Montana, field station of the Office of Western Irrigation Agriculture.

TOLERANCE OF SALINITY IN GAMMARUS LIMNÆUS.

Gortner and Harris (Science, n. s., 53:460–462, 1921) have noted the occurrence of *Gammarus limnœus* in the saline water of the Terrace Crater of the Sevier Desert, an occurrence showing the wide tolerance of this normally fresh-water species.

COOPERATIVE STUDIES ON HUMAN BASAL METABOLISM.

Dr. Harris, in cooperation with Dr. F. G. Benedict, Director of the Nutrition Laboratory of the Carnegie Institution of Washington, has completed a study of the variation of the basal metabolism in the individual subject (Jour. Biol. Chem., 46 : 257–279, 1921). This supplements the investigation of the variation of basal metabolism from subject to subject published as an Institution volume two years ago.

BIOMETRIC METHODS.

Dr. Harris has, as heretofore, devoted some time to biometric methodology. Formulæ for the determination of the correlation of size and of growth increments in the developing organism have been given by Harris (Proc. Soc. Exp. Biol. Med., 18 : 4–5, 1921) and applied by Harris and Reed (Biol. Bull., 40 : 243–288, 1921).

CULTURE METHODS.

Dr. A. M. Banta has published in Science the results of more than five years' experience in rearing Cladocera. He recommends a culture solution in which the bacteria that form the principal food of the Cladocera will multiply at the required rate.

ADMINISTRATIVE RECORD.

ARCHIVES OF THE EUGENICS RECORD OFFICE.

The care of the archives remained in the hands of Miss Louise A. Nelson until June 1, 1921. Thereafter it was assumed by Dr. Elizabeth B. Muncey. Miss Helen Bowen and Miss Helen Brown were indexers.

On September 1, 1921, it was estimated that there was a total of 818,851 cards in the Sextuple Index and 12,000 in the Persons Index. The total number of books in the archives was 1,363. The field reports (F) number 50,854 sheets; the Special Traits file (A) amount to 22,039 sheets; of the Records of Family Traits (R), and M files there are 3,752 numbers; and of the Family Distribution of Personal Traits (D), 1,711 sheets.

During the summer we were able to make use of the assistance of a number of college students in the preparation of material for the archives and in the analysis of records. Misses Laura Craytor, Bess Lloyd, and Henrietta Yates assisted in collecting standards of morbidity rates for 10,000 individuals from the R files, and in collating eye and hair color data. Misses Elizabeth Austin and Isabelle M. Whitefield mounted clippings of biographies, genealogies, and special traits.

COLLABORATORS.

The Eugenics Record Office has come to rely a great deal upon the assistance of collaborators who have furnished large amounts of manuscript material. Among those who have contributed this year are the following: Whittier State School (California), Dr. F. C. Nelles, superintendent, and Bureau of Juvenile Research at Whittier, Dr. J. H. Williams, director; Dr. David F. Weeks, superintendent Skillman State Village for Epileptics; Dr. F. C. Haviland, superintendent State Hospital, Middletown, Connecticut; Professor W. S. Monroe, State Normal School, Montclair, New Jersey; Professor E. Whittaker, Elmira College; Professor L. S. Ross, Des Moines; Professor F. S. Chapin, Smith College; Dr. L. W. Rapeer, Washington, D. C.; Miss Rosemary F. Mullen, Washington Irving High School, New York; Professor J. E. Peabody, Morris High School, New York; Dr. R. C. Benedict, Stuyvesant High School; Dr. Elizabeth F. Byrnes, Girls' High School; Professor W. M. Barrows, Ohio State University; Professor A. J. Goldfarb, College of the City of New York.

TRAINING CLASS.

In the training class for eugenical field workers 10 young women completed their training. Of these 5 were from New York State and 4 of these took the State examination for admission to the civil-service list as an entrance to State hospital service, as field worker. They have all received appointments. Of the others, two are already appointed at Letchworth Village, New York, one at Spring City, Pennsylvania, and one at Washington University Medical School. One is awaiting an expected appointment. The remaining one has married.

The following clinics were attended: At the State hospitals for the insane at Kings Park, Central Islip, and Ward's Island; at institutions for the feeble-minded at Letchworth Village, Randall's Island, and Brunswick Home, Amityville, Long Island; at the Manhattan Eye and Ear Hospital; at the Hospital for Ruptured and Crippled, New York; at the State Hospital for Crippled Children at West Haverstraw, New York; and at the House of Refuge, New York. The medical examinations at Ellis Island were visited. Actual field-work was done at Commack, Long Island; and with the families of inmates of the Kings Park Hospital. Professor H. H. Wilder, of Smith College, and Dr. Frederick L. Reichert, of Johns Hopkins University Medical School, collaborated in the training of this class.

ESTABLISHMENT OF DEPARTMENT OF GENETICS.

In accordance with the recommendation of the Executive Committee of the Institution at its meeting of October 15, 1920, the Board of Trustees of the Institution at its meeting of December 10, 1920, voted that a Department of Genetics should be organized by the consolidation of the Department of Experimental Evolution and the Eugenics Record Office, and that "the Department of Experimental Evolution and the Eugenics Record Office . . . . . be hereafter designated as the Sections of Experimental Evolution and the Eugenics Record Office respectively, of the Department of Genetics." Also, "that the proposed Department be placed officially, as it has already been in fact, under the administration of Dr. Charles B. Davenport, with the title Director of the Department of Genetics." Since the sections are physically separated and since the methods of work in the sections is quite different, the following assistant directors were appointed: Dr. C. C. Little, of the section of Experimental Evolution, and Dr. H. H. Laughlin, of the Eugenics Record Office, of which he had been superintendent from its foundation.

SPECIAL ACTIVITIES OF AND CHANGES IN STAFF.

Assistant Director Laughlin entered upon his new duties June 1, 1920, at the expiration of his leave of absence. During the summer he had charge of the training class, assisted by Dr. F. L. Reichert, of Johns Hopkins University. Assistant Director Little has acted as secretary-general of the Second International Congress. During the summer he had the cooperation in his researches of a considerable number of temporary collaborators and assistants, who were, for the most part, engaged on the genetics of cancer. Dr. A. F. Blakeslee has similarly organized a temporary corps of investigators which has assisted in the work on *Datura*. Dr. J. A. Harris, besides maintaining here his biometric laboratory, has made field studies in Florida and in the Great Desert, especially Utah and Arizona, where he has had a number of temporary associates. Dr. O. Riddle has continued his work on the physiology of reproduction in pigeons. Dr. A. M. Banta has continued his investigations into the origin and characters of the fauna of caves, while maintaining strains of Entomostraca now in between the second and third hundredth generation. Dr. C. W. Metz continued his cytological studies on genetics of Diptera; during the summer he took a vacation enforced by eye-strain. Dr. E. G. Anderson has been associated with Dr. Metz and has undertaken especially a systematic analysis of the foundations of the theories of linkage, crossing over, non-disjunction, factorial interaction, mutation, and gene constitution. Dr. Banker has continued his work on aristogenic families. This study made necessary a trip to study the records of certain eastern colleges. Dr. A. H. Estabrook has continued his work on the Ishmaelites of Indiana and has devoted some time to the direction of other social investigations in that state. Dr. Elizabeth B. Muncey is in charge of the archives of the Eugenics Record Office in place of Miss L. A. Nelson, who has been engaged in field-work in New York City, especially on bone abnormalities, in which she was aided by the cooperation of Dr. F. W. Taylor. With the organization of the Department of Genetics, Mr. G. H. Claflin was made chief clerk and Mr. George Macarthur superintendent of buildings and grounds.

GEOPHYSICAL LABORATORY.[1]

ARTHUR L. DAY, DIRECTOR.

This report, the fifteenth in annual succession since the founding of the Geophysical Laboratory, may properly take note of a gradual change in the outlook over our field of research as time goes on and experience increases. When it was first proposed to study quantitatively, in the laboratory, the manner of formation of the igneous rocks, the questions which arose in the minds of those interested were mainly questions of practicability and not of desirability or of the scope of the task. This had long been deemed to be not only a desirable but an indispensable chapter in the history of the earth, which had hitherto to be viewed from a distance, with the telescope of speculation, as it were, because of the physical difficulties of near approach. Neither was any attempt made to define its proper scope. A telescopic view of a new field of activity does not at once reveal boundaries nor suggest limitations. Even the prefix supplied to create the names "Geophysics" or "Geochemistry" suggests no limitation upon the ordinary use of the terms physics and chemistry such as is implied in "Astrophysics."

The real difficulty which presented itself persistently in the early consideration of the project was one of practicability. Could such a field of research, which in the minds of geologists comprehended the most majestic of terrestrial phenomena, be brought into the laboratory with hope of finding successful elucidation there? Could an attack from the experimental side yield quantitative relations, or would it provide no more than feebler imitations of natural phenomena, powerless alike for analysis or prediction? Would it be possible to make a competent study of all the processes of rock formation, even with all the available resources of physics and chemistry?

The reactions in igneous rocks might be expected to occur almost exclusively in a region of temperatures so high that even their measurement could not then be regarded as certain. Would it, then, prove practicable to detect and measure transfers or transformations of energy at those high temperatures, to segregate for purposes of identification the participating components in any transfer of energy in a silicate solution, to determine the heat of fusion, the degree of viscosity, the power of convection, the separation of the products of early crystallization within the magma under the action of gravity or temperature change or of mobile volatile components, or, indeed, to determine when a condition of equilibrium capable of precise definition had been reached? Unless it should prove practicable to establish and recognize a state of equilibrium, there was little hope of definition of anything in such a field as this, for it is plain that mere observation of a process of change without being able to determine the points between which the change was occurring would rarely permit of reproduction, still less of definition. Without the power of reproduction, or of definition in terms of the state of the participating materials, or the magnitude of the participating forces, anything approaching a science of rock formation or of mineral chemistry is little more than a concept—a desideratum without tangible reality.

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[1] Situated in Washington, District of Columbia.

To-day the telescopic picture is quite different. The field has been brought nearer and many details of it are now in plain view. Temperatures appropriate to the rock-forming processes can be provided without difficulty and measured with but little more uncertainty than the temperatures of every-day life. Pressures adequate to insure the participation of the more volatile ingredients of rock formation are also available and properly subject to control and measurement. Criteria have not been found lacking through which to recognize and define equilibrium, together with the magnitude and direction of its displacement with changes in the reacting forces. Heat changes are determinable both in quantity and direction. Latterly, even the atomic composition and structure of the participating crystalline minerals are becoming capable of photographic record. In short, there is abundant experience now available through which we may assure ourselves that the relations between minerals participating in rock formation are orderly and subject to precisely the same laws as similar relations in solutions in more conventional physical chemistry.

In consequence of these assurances, obtained after the expenditure of much effort and ingenuity, the character of the program of geophysical research from year to year may be seen to change very appreciably both in this Laboratory and elsewhere. It is not so much a matter for discussion now as formerly, whether this or that method of temperature measurement is competent in a temperature region which is difficult of access, or whether the moment of change of state is revealed by the appearance of a melting mineral or solution. The competence of observations of this kind is now capable of precise appraisal and many modes of verification are available. In consequence of such progress the agenda-list in any recent year will be found to contain progressively more of the application of recognized methods to current geologic problems, while less attention is given to the elaboration of the methods themselves. In terms of the whole effort expended, the major portion of the task hitherto has been concerned with the demonstration of the effectiveness of certain lines of study and of the scope and trustworthiness of the available methods of attack. So far as these efforts have been successful, hitherto inaccessible problems in the earth's formation now lie open for study and are being attacked with increasing success.

To illustrate from the work of the current year:

Comparatively little work has been done in the investigation of those geophysical problems in which one of the components is volatile, such, for example, as the formation of carbonates, hydrates, sulphates, and the oxides of certain metals. Though the foundations for the theoretical groundwork were laid years ago by Willard Gibbs, the experimental side of the problem has been neglected in the past, chiefly because of the difficulty of attaining equilibrium within the limited time available for a single laboratory experiment and because of the complexity of the systems encountered.

A recent investigation of the system copper-oxygen, undertaken here, has furnished data for extending the equations of Gibbs to apply to a particular case, has formed a basis for estimating the behavior of other similar systems, and has been the means of developing the necessary technique for the investigation of more complex systems.

The investigation itself disclosed as solid phases in this system only copper, cuprous oxide, and cupric oxide, all three of which occur as natural minerals, and gave no evidence whatever of solid solution in the system. Measurements were successfully made of pressure and composition throughout the temperature range between 900° and 1235° C. at oxygen pressures varying from 0.02 millimeter of mercury to 55 atmospheres. The data were applied to the calculation of the energy changes involved in the dissociation and to the calculation of the melting-point of cuprous oxide. There is still some work to be done in that part of the system lying between copper and cuprous oxide, but in a field which is of chief importance to the metallurgist.

Having regard for the potential application of such methods and criteria in the analysis and study of geological problems, it is especially interesting to consider the composition of the igneous rocks as presented in a correlation of chemical analyses by Dr. Washington of this Laboratory in association with Dr. F. W. Clarke of the Geological Survey. For a number of years the effort has been made to apply the data derived from the chemical analysis of igneous rocks to the study of some of the broader aspects of petrology, and more especially of the relation of the elements in igneous rocks and their distribution over the earth. A preliminary statement of some of the results of this study was presented before the Franklin Institute in December 1920, under the title "The chemistry of the earth's crust." Certain particular features of the subject, especially the chemical composition of the average igneous rock of the earth's crust and the relations of the chemical elements in minerals and igneous rocks, are set forth in a forthcoming Professional Paper of the U. S. Geological Survey, after which the general results of the study will appear in book form.

A new average of the igneous rocks of the earth has been calculated which is based upon 5,159 good analyses of rocks from all parts of the earth, which were brought together and classified in Professional Paper 99 of the Geological Survey (1917). In its main features this resembles other averages made previously, but as it is based on the largest number of good analyses yet available it is the most authoritative. Included in it are estimates of the percentages of several of the rarer elements, such as zirconium, barium, strontium, chromium, vanadium, and nickel.

It appears that 12 elements (oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium, titanium, phosphorus, hydrogen, and manganese) constitute about 99.6 per cent of the earth's crust, leaving only about 0.4 per cent for all the other elements (about 80 in number). It is noteworthy that (with the exception of iron, aluminum, nickel, and manganese) the common and "every-day" metals necessary for our civilization (such as copper, silver, gold, zinc, tin, lead, mercury, platinum, antimony, and bismuth) are either not present in igneous rocks or are present in scarcely detectable amounts.

Study of the chemical relations of the elements found in minerals and rocks shows that they are divisible into two groups. The "petrogenic" group comprises all of the most abundant elements, which compose the igneous rocks, the oceanic waters, and the atmosphere, together with some rarer ones. These petrogenic elements occur typically as oxides, simple silicates, alumino-silicates and other complex silicates, aluminates, fluorides, chlorides, and sulphides. They do not normally form mineral arsenides, antimonides, selenides, tellurides, bromides, or iodides, nor do most of them occur in nature uncombined. The "metallogenic" elements are not found in igneous rocks (except rarely in traces), but they occur as ores. Most of them occur frequently as native metals, and their typical mineral compounds are sulphides, selenides, tellurides, arsenides, antimonides, sulpharsenites and other sulpho-salts, bromides, and iodides. They do not occur normally as primary oxides, silicates, aluminates, fluorides, or chlorides. With the metallogenic elements are included the metals (copper, silver, gold, etc.) mentioned above.

The distinction is well brought out in the periodic classification of the elements, in which the two groups are sharply separated and occupy the two opposite sides of the table, with the "triad" elements (such as iron, cobalt, and nickel) transitional between them. It is probable that the sharp separation of the two groups is significant of important differences in the relations of the elements to the structure and the evolution of the earth. There is reason to believe that, while the outer part of the earth (the "crust") is composed almost wholly of petrogenic elements, the central core is probably composed of metallogenic elements, with an intermediate zone of iron-nickel-cobalt, probably associated with borides, carbides, phosphides, and sulphides. A similar distribution is believed to obtain in the sun, and there may be analogous distributions in the stars and nebulæ, as indicated by the spectroscope.

The study of the average chemical composition of the igneous rock of different areas brings out many interesting facts. While the several continents resemble each other in general chemical composition, yet there are notable differences among them; also, the averages of different countries and parts of continents differ among themselves still more widely. The averages of the United States and of Europe (which are best known) most nearly resemble the general earth average. The average composition of the rocks of the Atlantic and Pacific Ocean floors is very different from those of the continents and of most of the larger land areas.

From the average chemical composition of the igneous rocks of any given area it is possible to calculate the density of this portion of the earth's crust. This has been done for the continents, for the floors of the Atlantic and Pacific Oceans, and for many countries and larger land areas. The average densities are found to vary within rather wide limits. Thus, the average density of the earth's crust is 2.77, that of Asia is 2.72, while that of the floor of the Pacific is about 3.00.

There is an interesting and significant inverse relation between the average density and the mean elevation above sea-level: the lower the density (or the lighter the average rock) the higher the mean elevation. This is generally true all over the earth and is most strikingly shown along a zone around the earth in about latitude 45° north, which crosses the United States, Europe, Asia, and the Atlantic and Pacific Oceans. The curves of rock density and land elevation vary in opposite sense with scarcely an exception.

The establishment of this relation, which is based on a very large number of data derived from many and widely scattered portions of the earth, is of special interest in connection with the theory of isostasy; namely, that the lighter portions of the crust tend to rise, while the heavier tend to sink, so that the various portions of the crust maintain a state of balanced equilibrium and are not sustained primarily by the principle of the arch. Gravity observations with the pendulum or plumb-bob suggested this concept of the crustal conditions, and this most recent evidence is confirmatory of the theory, although the subject is approached from such an apparently unrelated starting-point as the chemical analysis of igneous rocks.

Another feature of this year's program has been to bring together, in convenient and accessible form, the considerable body of information about silica and the silicates which has accumulated as the result of experimental work during the last twenty years, but is still rather inconveniently scattered through the scientific periodicals. The need for such a work has been felt by several groups, each interested in the silicates from a different point of view.

The needs of the group of scientific investigators are easiest to meet. A simple collection of the principal facts, accompanied by a thorough bibliography, will satisfy them, for they are already familiar with much of the material. But a thorough bibliography is worse than useless to some of the groups concerned. The petrologists, for example, desire the new physical and chemical facts about silicates, not in the form in which they were originally discovered, but interpreted in terms of the forms with which a petrologist works, namely, the natural minerals and rocks. The ceramic chemists and engineers, on the other hand, desire the same facts freed from their burden of experimental and theoretical proofs, just as in the case of the petrologist, but interpreted this time in terms of technical products—porcelain and glaze, bricks and pottery, refractories, and manufacturable glass. Last, and most important, is the group made up of students in colleges and technical schools, whose interest is in the future rather than in the present, and whose needs are therefore the hardest of all to meet. They want *all* the facts, for if history furnishes any guidance it is probable that the important facts and relations of the future will be drawn in part from the unimportant facts of to-day.

The effort has therefore been made to provide a reference book on the facts and theories of the silicates which may find application alike to the needs of the student of ceramics, of mineralogy, of petrology, or of inorganic chemistry.

The classification of the subject-matter cuts right across some of the standard groupings of mineralogy, but is expected fully to justify itself by its elasticity and by the new relations which can thus be brought out. Silicate theory during the past fifty years has been too dependent upon the analogies of organic chemistry, and sufficient use has not yet been made, in silicate research, of the principles developed in recent years by investigators in the field of physical chemistry. In the long step forward now being taken in our knowledge of molecular and atomic structure, investigators should draw very considerable aid from the large body of facts already assembled by the mineralogists and other students of silicate chemistry.

It may be of interest to record the fact that with the forthcoming publication by the War Department of Colonel Wright's book, "The manufacture of optical glass and of optical systems" (reviewed on page 174), the numbered publications on optical glass resulting from the war activities of this Laboratory will reach forty.

Brief reviews of the papers published by members of the Laboratory staff during the current year will be found on the following pages:

PUBLICATIONS.

(386) Tridymite crystals in glass. N. L. Bowen. Am. Mineralogist, 4, 65–66 (1919).

Crystals of tridymite similar to those described by Le Chatelier in a French glass were found in a specimen of light flint glass. Question is raised regarding Le Chatelier's conclusion that tridymite is the only form of silica stable at temperatures above the stability range of quartz. Cristobalite forms freely and persists indefinitely above 1470° in glasses capable of precipitating silica at such temperatures and is therefore the stable phase above 1470°.

(387) Abnormal birefringence of torbernite. N. L. Bowen. Am. J. Sci., 48, 195–198 (1919).

Torbernite from Cornwall was found to have totally different optical properties from those ordinarily assigned to it. Torbernite is usually described as uniaxial and negative with indices 1.592 and 1.582. The present torbernite was found to have a mean index of about 1.62 and to give very abnormal interference colors, which are always red, blue, or purple, whatever the thickness of the section. Measurement of the indices ω and ϵ for various wave-lengths showed that the mineral has very weak positive birefringence for the red end of the spectrum but is negative for the blue end. For green light of 515μ wave-length it is isotropic. This form of torbernite is the heptahydrate or the first stage in desiccation from the dodecahydrate, which desiccation may take place spontaneously.

(388) Cacoclasite from Wakefield, Quebec. N. L. Bowen. Am. J. Sci., 48, 440–442 (1919).

Chemical, microscopic, and crystallographic evidence all points to the fact that cacoclasite is a pseudomorph (essentially a paramorph) of grossularite after sarcolite with calcite and apatite filling the voids produced by the reduction of volume involved in the change.

(389) Crystallization-differentiation in igneous magmas. N. L. Bowen. J. Geol., 27, 393–430 (1919).

In this paper some of the objections which have been raised against the theory of crystallization-differentiation are considered; and its adequacy to explain certain phenomena, for which it has been considered to fail, is pointed out. The supposed advantages of liquid immiscibility in explaining discontinuous variations are considered, and reasons are given for believing that no such advantages exist. On the basis of crystallization, explanations are suggested for discontinuous variations, particularly those noted in the association gabbro-granophyre. A suggestion is made as to the origin of primary banding with particular reference to the Duluth lopolith.

(390) Echellite, a new mineral. N. L. Bowen. Am. Mineralogist, 5, 1–2 (1920).

Small spheroidal masses of a radiating fibrous mineral occurring in a basic intrusive from Sextant Portage, Abitibi River, Northern Ontario, are found to be made up of a new mineral. The optical properties are $\alpha = 1.530$; $\beta = 1.533$; $\gamma = 1.545 \pm .001$; $+$; $2V = 50 \pm 5$. The elongation is β and the crystallization probably orthorhombic. Chemical analysis gave the formula $(Ca, Na_2)O.2Al_2O_3.3SiO_2.4H_2O$. The name echellite is proposed for this new mineral in allusion to the stepped (1, 2, 3, 4) ratios.

(391) Differentiation by deformation. N. L. Bowen. Proc. Nat. Acad. Sci., 6, 159–162 (1920).

An examination into the tendency of deformation of a partly crystallized igneous magma toward the separation of liquid from crystals and the consequent production of a differentiated mass. An effect of this kind is believed to be a factor of importance in the production of discontinuous differentiation, of monomineralic types, of complementary dikes, and of primary banding.

(393*a*) Le rioliti di Lipari. Henry S. Washington. Boll. Soc. Geol. Ital., 39, 141-159 (1920).

This is a translation into Italian of the paper reviewed on page 173 of the Annual Report for 1920 (The rhyolites of Lipari, Am. J. Sci., 50, 446-462).

(396) The annealing of glass. L. H. Adams and E. D. Williamson. J. Franklin Inst., 190, 597-631; 835-870 (1920). (Papers on Optical Glass, No. 32.)

The annealing of glass was one of the numerous problems encountered during the participation of the Geophysical Laboratory in the development and manufacture of optical glass. When molten glass is cooled it usually acquires internal stresses and is then said to be "strained." Excessive stresses can not be tolerated in any kind of glass, since they render the glass liable to break when handled or heated again, and in the case of optical glass even a moderate amount of strain causes troublesome warping of finished lenses and prisms. The prevention of internal stresses in glass (and its removal when present) is a problem which requires for its complete solution a knowledge of various thermal, optical, and elastic constants of the relations between such factors as rate of heating, temperature gradient, and stress distribution in terms of the above-mentioned constants. It is shown that the process of annealing glass can best be carried out if we know, for the various glasses and for the various temperatures, the rate of release of the internal stresses. The results of such measurements for nine kinds of glass are here presented. The release of stress at constant temperature was found to proceed usually according to the equation $\frac{1}{F}-\frac{1}{F_0}=At$, in which F is the stress at any time t, F_0 is the initial stress, and A is a constant for the particular glass at a particular temperature and is a measure of the rate at which stresses are relieved. The variation of this rate with temperature follows the equation $\log A=M_1\theta-M_2$, in which M_1 and M_2 are constants for a particular glass.

At any temperature a glass requires a certain *annealing-time.* This is arbitrarily defined as the time required to reduce the stress (in optical units) from 50 to $2.5\mu\mu$ per centimeter. For convenience of reference, the 150° interval lying immediately below the temperature at which the annealing-time is two minutes is called (also quite arbitrarily) the *annealing-range.* At temperatures below the annealing-range as thus defined very little permanent stress can be introduced.

Concrete directions are given for annealing optical glass. The procedure to be followed for other kinds of glass, such as plate-glass, bottles, chemical glassware, etc., is also indicated. Mathematical analysis of the problem shows that the best method for annealing requires that the glass be held at constant temperature (below the customary annealing-point) for the appropriate time and then cooled at an increasing rate. It is of interest to note that the larger the piece of glass the lower the annealing temperature. Finally, there are presented several equations which are convenient for calculating the internal stresses due to heating or cooling solids of various shapes.

While the original object of this investigation was to put on a quantitative basis the operations connected with the annealing of glass, it was found that many of the results have an important bearing on certain problems of geophysics. For example, the relief of internal stresses in glass probably belongs in the category of elastico-viscous flow and is thus connected with such processes as the tidal deformation of the earth's crust. Moreover, the formulæ expressing the relation between temperature differences and stress distribution are directly applicable to the phenomenon of the "jointing" of rocks.

NOTE:—Certain phases of the subject have already been covered in previous publications from this Laboratory, as, for example: Temperature distribution in solids during heating or cooling, by E. D. Williamson and L. H. Adams, Phys. Rev., 14, 99–114 (1919); The cooling of optical glass melts, by H. S. Roberts, J. Am. Ceram. Soc., 2, 543–563 (1919); The relations between birefringence and stress in various types of glass, by L. H. Adams and E. D. Williamson, J. Wash. Acad. Sci., 9, 609–623 (1919); Strains due to temperature gradients, with special reference to optical glass, by E. D. Williamson, J. Wash. Acad. Sci., 9, 209–217 (1919). In the present paper annealing of glass is treated as a whole.

(397) The chemistry of the earth's crust. Henry S. Washington. J. Franklin Inst., 190, 757–815 (1920). (Reprinted, Smithsonian Misc. Coll., 1921.)

After brief consideration of the interior of the earth, the general character of igneous rocks is discussed, and the presence of water-vapor and other gases in the magma is pointed out. In the discussion of the mineral character of rocks, stress is laid on the fact that the number of essential rock-forming minerals is very small. These are mostly silicates of aluminum, iron, magnesium, calcium, sodium, and potassium. Any two or more of these minerals (with two exceptions) may occur together and in all proportions.

The chemical character of igneous rocks is summarized and the ranges and maxima of the various constituents are given. The average igneous rock is considered and, after some discussion of the sources of error involved in the calculation, a new average (based on 5,159 analyses) is given. The average rock is shown to be approximately a granodiorite.

The average composition of the earth's crust in terms of elements is given. Twelve elements (oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium, titanium, hydrogen, phosphorus, and manganese) make up 99.61 per cent of the crust.

The elements are referred to two main groups in the periodic table: (1) the "petrogenic" elements, characteristic of and most abundant in igneous rocks, of low atomic weight and occurring normally as oxides, silicates, chlorides, and fluorides; (2) the "metallogenic" elements, rare or absent in igneous rocks but occurring as ores, of high atomic weight, and forming in nature metals, sulphides, arsenides, etc., but not oxides or silicates. The suggestion is made that beneath the silicate crust of petrogenic elements is a zone essentially of nickel-iron, and beneath this a central core of the metallogenic elements. This vertical distribution is in accord with Abbot's views as to the distribution of the elements in the sun.

In igneous rocks and minerals the elements show a correlation, in that certain of them are prone to occur with others, and a similar limited correlation is apparently true of the animal and vegetable kingdoms.

The idea of "comagmatic regions," that is, the distribution of igneous rocks in regions of chemically related magmas, is discussed and some are briefly described.

The calculation of rock densities from their chemical composition is discussed, and the average chemical compositions and densities of the continental masses and oceanic floors are given. It is shown by these that the average densities of the continents, ocean floors, and various smaller regions of the earth stand in inverse relation to their elevations. The bearing of this relation of average density and elevation on the theory of isostasy is pointed out, and it is shown that the data presented are confirmative of the theory.

(398) The system cupric oxide, cuprous oxide, oxygen. F. Hastings Smyth and H. S. Roberts. J. Am. Chem. Soc., 42, 2582–2607 (1920).

It has been shown that solid solution of cuprous oxide in cupric oxide does not take place in the temperature range where both oxides remain solid. Previous results indicating such solution may probably be explained by lack of careful temperature control, and by possible adsorption of nitrogen in solid cupric oxide, giving high initial pressures. Results below the eutectic points are in agreement with those of Foote and Smith.

The pressure-temperature equilibrium curves for the system cupric oxide, cuprous oxide, oxygen have been established over the range (1) in which the oxides remain solid below the eutectic point, and (2) above the eutectic point, where cupric oxide remains the solid phase up to 1233° C.

The pressure and temperature of the quadruple (eutectic) point for the system have been established from the intersection of these two curves. The quadruple point lies at 1080.2° C. and 390 mm. pressure.

The general direction of the equilibrium curve for the system when cuprous oxide remains the only solid phase has been indicated, and it has been proved that, in accordance with theory, the equilibrium pressure drops in this case with rise in temperature. It has been shown that pure cupric oxide does not melt without dissociation below 1233° C.

(399) The problems of volcanology. Henry S. Washington. Proc. Nat. Acad. Sci., 6, 583–591 (1920).

The general and most important problems presented by volcanology are briefly discussed. They include both the problems pertaining to volcanology proper and those related to other sciences, especially the sciences represented by sections in the Geophysical Union. Some recommendations for lines of work are made.

In volcanology proper are suggested the need of a general catalogue of volcanoes; a record of all eruptions and the study of their phenomena, and hence the advisability of notification of impending or sudden eruptions so that they may be studied from the beginning by volcanologists; the investigation of little-known volcanoes, especially of the Pacific; the need of continuous study of volcanoes, and hence the need of several volcano stations (such as those on Kilauea and Vesuvius), where systematic and continuous records and observations may be made; the study of thermal gradients by borings at volcanoes and also in non-volcanic localities.

Various problems of volcanology are discussed as related to geodesy; seismology (continuous study of volcanic earthquakes and tremors and changes of level); meteorology (relation of eruptions to weather, barometer, etc., also dust and "blue suns"); terrestrial magnetism (observations of electrical and magnetic phenomena during eruptions); physical oceanography (submarine eruptions, collection of volcanic data from ships' logs, study of deep-sea deposits); geophysical-chemistry (formation, chemistry, and petrography of lavas, study of volcanic gases and fumarole salts, etc.); effect of volcanic gases and ashes on vegetation and reclamation; investigation of character of lunar lavas (?) by study of their refractive indices by angle of polarization.

(400) An outline of geophysical-chemical problems. Robert B. Sosman. Proc. Nat. Acad. Sci., 6, 592–601 (1920).

This paper constitutes one of seven reports prepared for the American Geophysical Union and covering various phases of geophysics as distributed among the seven sections of the Union.

The subject-matter of geophysical chemistry may be defined as "the physical properties and chemical reactions of the substances and aggregates that make up the earth." It may therefore be roughly divided into two parts: (A) properties and reactions of materials accessible at the earth's surface; (B) properties and reactions of materials in the earth's interior. Each of these may again be subdivided as follows: (1) properties and reactions of individual chemical substances, for example, the silicate minerals; (2) properties and reactions of aggregates, for example, oceanic water, silicate rocks; (3) properties and reactions of larger units of matter, for example, glaciers, batholiths.

The lines of research now being followed in these various branches of the subject are briefly summarized or commented upon.

(401) Unification of symbols and diagrams. W. P. White. Science, 51, 414–417 (1920).

A widespread effort has been made to unify the symbols used in physical and chemical formulæ. This movement has been mainly directed to quantities of wide and general use, such as time, temperature, volume, expansion. It is suggested in this paper that the movement might well be extended to special subjects, treating each partly by itself. Thus, in calorimetry, there are several temperatures to be dealt with which might better be distinguished in the same way by different writers; in the study of heat engines, still other temperatures, needing a different designation. It is also suggested that the labor of all these details might be largely thrown on the writers in the various subjects, with a committee to act as referee but not to take the burden of prescribing for the whole field. If no such authoritative committee can be obtained, writers themselves can accomplish much by cooperation, or even by following the rule of not wantonly changing a notation already in use. The same suggestions apply to the lettering of diagrams.

(402) Note on augite from Vesuvius and Etna. H. S. Washington and H. E. Merwin. Am. J. Sci., 1, 20–30 (1921).

In this paper are given a description and analysis of the crystals of augite collected by Dr. Washington at the bottom of the crater of Vesuvius in 1914, with crystallographic determination by Dr. Merwin. The fact that the chemical composition of the crystals is almost identical with that of pyroxenites of Monte Somma, described by Lacroix, is mentioned, and the relative merits of the gravitative adjustment and fractional crystallization theories of certain forms of differentiation are discussed.

Crystals of augite from Monti Rossi, of the eruption of 1669 at Etna, are also described, with a new analysis and optical determinations. It is pointed out that no good analyses of the augites of either Vesuvius or Etna are to be found in the literature. The early work of Spallanzani (circa 1790) is described briefly, and it is shown that he was the first to determine the relative melting-points of the feldspars and augite and to measure their relative magnetic susceptibility, and that therefore he is to be regarded as the first experimental geophysicist. There is also given a comparison of the chemical compositions of various Italian augites with the lavas that contain them.

(403) Note on crucibles used in rock analysis. Henry S. Washington. J. Wash. Acad. Sci., 11, 9–13 (1921).

An experience in rock analysis with a palau and an iridium-platinum crucible is described. It was found that, for the fusion with sodium carbonate, the cold cake frees itself much more readily from palau (not a case of its adhering having been noted during many fusions) than from iridium-platinum, and still more readily than from pure platinum. Two series of weighings showed that after 47 fusions the palau crucible lost, on an average, 0.2 milligram per fusion, while the iridium-platinum crucible lost, on an average, 0.47 milligram. The greater loss of the latter is probably to be ascribed in part to loss of iridium by volatilization.

(404) A meteor fall in the Atlantic. Henry S. Washington. Science, 53, 90–91 (1921).

A note putting on record the newspaper report of the fall of a meteorite in the Atlantic Ocean in October 1906.

(405) An outline of the application of the theory of space groups to the study of the structure of crystals. Ralph W. G. Wyckoff. Am. J. Sci., 1, 127–137 (1921). The crystal structure of magnesium oxide. Ibid., pp. 138–152.

In the first paper are briefly considered such details of the theory of space groups as are of importance in the application of this theory to the determination of the structure of crystals. Point groups, space lattices, and space groups are illustrated by simple examples. A discussion is given of the relations between space groups and crystals and of those modifications in the results of the theory of space groups which are required in order that it may serve as the basis for a general method for the study of the structure of crystals.

In the second paper the method of studying the structure of crystals which arises from the point of view outlined above is applied to a relatively simple case in the discussion of the structure of magnesium oxide.

An attempt has been made, using Laue photographs and X-ray spectrum measurements, to get a *unique* solution for the crystal structure of magnesium oxide. If it possesses holohedral symmetry, then the only simple structure which is possible is the "sodium-chloride arrangement."

Certain cases of grouping showing tetartohedral symmetry, and two more complicated holohedral arrangements, each with 32 molecules associated with the unit, are in agreement with the existing experiments. These other possibilities, however, differ but slightly from the "sodium-chloride arrangement," and can not be positively treated by the experimental facilities now available.

(406) The determination of the structure of crystals. Ralph W. G. Wyckoff. J. Franklin Inst., 191, 199–230 (1921). (Reprinted, Smithsonian Misc. Coll., 1921.)

This discussion aims to give a brief survey of the field of the determination of the structure of crystals as it exists at the present time. The most essential events in the development of this work are mentioned, the existing means of experimentation are outlined, and some of its present limitations are discussed, together with some of the kinds of problems to which a knowledge of the arrangement of the atoms in crystals has contributed and may be expected to contribute.

(407) The compressibility of diamond. Leason H. Adams. J. Wash. Acad. Sci., 11, 45–50 (1921).

By the use of pressures up to 10,000 megabars, the compressibility of clear colorless diamond was measured and found to be 0.16×10^{-6} per megabar. This is a remarkably low value; indeed, of all substances whose elastic behavior is known, diamond is by far the most incompressible. Its nearest rival, tungsten, is nearly twice as compressible.

From a consideration of certain formulæ connecting various physical properties of solids it is shown that the low compressibility of diamond might be predicted from its high melting-point, its low expansion coefficient, and its high atomic frequency.

(408) The distribution of scientific information in the United States. Robert B. Sosman. J. Wash. Acad. Sci., 11, 69–99 (1921).

The production of new information in the United States is much better organized than its distribution. It is distributed through five main channels: (1) by personal communication or through the "informational middleman;" (2) by public lectures; (3) by the museum and public exhibition; (4) by the printed page—books, scientific and technical periodicals, bulletins, general periodicals, newspapers, and separates; (5) by the cinematograph. Ineffective distribution results from disinclination to use new knowledge, a cause not discussed in this paper, and from the inaccessibility of scientific information arising from the bulky form in which it comes from the producer, its heterogeneous character, and the arithmetical or psychological limitations peculiar to each method of distribution. The bearing of these various factors on existing methods of distribution, both to producers of information and to the general public, is touched upon, and desirable or probable future developments are briefly discussed.

(409) Note on the measurement of the density of minerals. L. H. Adams. Am. Mineralogist, 6, 11–12 (1921).

The striking variations shown in different determinations of even the most simple and definite minerals indicate that there is room for improvement in the technic of density-measurement. In this note attention is called to the advantages of the "flat-top" pycnometer for measuring the density (or specific gravity) of minerals and other granular or powdered solids. With this pycnometer an accuracy of about 0.0001 can be obtained.

(410) War-time production of optical munitions. Fred. E. Wright. Army Ordnance, 1, 247–251 (1921). (Papers on Optical Glass, No. 33.)

In this paper a general statement is given of the development of the optical glass and instrument situation during the recent war. Some of the difficulties which arose and the measures taken to overcome them are described briefly. The records show that the methods for the manufacture of optical glass had first to be developed and placed on a routine basis; factory facilities had greatly to be increased; raw materials of adequate purity had to be obtained and transported; a personnel competent to handle the different phases of the problems had to be organized and trained to the several tasks. Methods for the adequate inspection of optical glass had to be adopted and a force of inspectors trained in their use. The manufacturing capacity of the country for optical instruments had to be increased greatly; new operators had to be trained, and the entire optical industry organized and coordinated. The rôles played in this connection by the manufacturers, the Geophysical Laboratory, the War Industries Board, and the War and Navy Departments are noted briefly. The significance of the optical industry in war time is emphasized, and means are suggested for the development during peace-time of a skeleton organization of optical engineers who, in the case of an emergency, might render effective aid in building up the optical industry to meet the needs of the field forces.

(411) The angular deflections produced on transmitted light rays by slightly incorrect interfacial angles of reflection prisms. Fred. E. Wright. J. Opt. Soc. Amer., 5, 193–204 (1921). (Papers on Optical Glass, No. 34.)

The interfacial angles of a reflecting prism of any given type may be measured directly on a goniometer or a spectrometer, or by means of delicate gages or specially mounted test plates such as the optical square. They may also be measured by the deflections produced by the prism on transmitted rays of light. A prism of the prescribed shape deflects the transmitted rays along a prescribed path. A prism of slightly incorrect interfacial prism angles deflects transmitted light rays so that these emerge along a direction slightly different from that prescribed; from this deviation it is possible to determine the degree of exactness of the interfacial prism angles. Methods of test based on this principle enable the observer at the same time to draw conclusions regarding the quality of glass in the prism and the degree of flatness of the prism faces; in short, to judge of the fitness of the prism as a component of any given optical system. In the present paper prisms of different types are considered, and sets of curves are shown in diagrams illustrating the deviations caused by slightly incorrect interfacial prism angles. From these curves the sensitiveness of the several optical methods which have been proposed for testing the accuracy of prism angles by the use of transmitted light rays can be detected directly and the suitability of each method thereby ascertained.

(412) The system copper: cupric oxide: oxygen. H. S. Roberts and F. Hastings Smyth. J. Am. Chem. Soc., 43, 1061–1079 (1921).

At temperatures below 1060° CuO dissociates with the formation of solid Cu_2O and O_2 gas, and Cu_2O with the formation of solid Cu and O_2 gas; solid solution, if it occurs at all, is so limited in extent as to be without appreciable effect on the dissociation pressures. Thus the system as a whole is of a very simple type.

Pure Cu melts at 1082.8°; Cu_2O at 1235° under an oxygen pressure of 0.6 mm. of mercury. Because of the high pressure necessary to prevent dissociation, the melting-point of CuO could not be determined; it probably lies above 1260° with a dissociation pressure of, perhaps, several thousand atmospheres. There is a eutectic at 1062°, about 0.013 mm. of mercury, 3.4 per cent Cu_2O and 96.6 per cent Cu by weight; a eutectic at 1080.2°, 402.3 mm. of mercury, 29.5 per cent CuO and 70.5 per cent Cu_2O by weight; another quadruple point at 1195° and about 0.66 mm. of mercury where solid Cu_2O is in equilibrium with gas and with two immiscible liquids whose composition lies between Cu and Cu_2O.

At 900° the dissociation pressure, i. e., the oxygen pressure under which CuO and Cu_2O may coexist, is 12.6 mm. of mercury; as the temperature rises, this pressure increases to 402.3 mm. at the eutectic temperature. At still higher temperatures the two oxides and oxygen can no longer exist in equilibrium, and one or the other disappears, giving place to a liquid whose composition is intermediate between CuO and Cu_2O. Where CuO remains as the solid phase, the equilibrium pressure increases with rising temperature, more and more rapidly, reaching 44,700 mm. of mercury at 1232.5°, the highest temperature investigated. Where Cu_2O remains, the equilibrium pressure decreases with rising temperature until it reaches 0.6 mm. of mercury at 1235°, the melting-point of Cu_2O.

We succeeded in determining only one of the P–T curves between Cu and Cu_2O: the dissociation pressure curve between the Cu–Cu_2O eutectic and the quadruple point at 1195°. From the latter point the dissociation pressures follow a curve, which finally joins and becomes continuous at the melting-point of Cu_2O with the P–T curve for Cu_2O-Liquid-O_2 described in the previous paragraph.

Since the system is not complicated, it was thought worth while to present a mathematical discussion of the various curves and to calculate, from the data, the heat of dissociation and the free energy changes of CuO at 1000°, as well as the heat of fusion of Cu_2O.

(413) Diffusion in silicate melts. N. L. Bowen. J. Geol., 29, 295–317 (1921).

The rate of diffusion in certain silicate melts has been determined experimentally by permitting diffusion against gravity of a heavy liquid into a lighter liquid. The concentration curves found are not coincident with any theoretical curve calculated on the basis of a constant value of the diffusivity, but can be interpreted on the assumption that the diffusivity varies with concentration and is less for concentrations corresponding to more viscous liquids than for those corresponding to less viscous liquids. Taking as representative of the "average diffusivity" the amount of material which penetrates into the upper layer, the following values of the average diffusivity (k) were found: for diopside into Ab_2An_1, $k=0.015$; for diopside into Ab_1An_1, $k=0.14$ to 0.3, depending on the proportions; and for diopside into Ab_1An_2, $k=0.2$, all in square centimeters per second.

The value 0.25 (close to the maximum experimental value) is taken as probably representing a fair estimate of diffusivity in magmas, and with this as a basis it is shown that such phenomena as the formation of border phases about large bodies of igneous rock by diffusion can not be considered possible in the time available for such action in a cooling magma. On the other hand, the formation of reaction rims about inclusions may be attributed to diffusion, though for very wide rims a considerable period of time will be required.

(414) Cords and surface-markings in glassware. F. E. Wright. J. Am. Ceram. Soc., 4, 655–661 (1921). (Papers on Optical Glass, No. 35.)

In all glass-melting and glass-forming operations there are a number of factors to consider, and the greater the number of definite facts the glass-maker or glass-worker has at hand regarding his particular type of glass, the better is he able to control the operations and the more uniformly excellent is the quality of the final product. Two of the disturbing phenomena which mar the appearance of glassware are surface markings and cords. In many instances surface markings are wrongly designated as cords, and the wrong remedy is applied by the glass-maker, who then tries one thing after another, thereby wasting time and money. Fortunately, methods are available for distinguishing between surface markings and cords, and also for determining the refringence of a cord relative to the glass surrounding it. The glass article is immersed in a tank of liquid of the same refractive index and viewed through the plate-glass sides of the tank, the line of sight being directed toward a distant source of light. Under these conditions surface markings disappear altogether, whereas cords and striæ are more clearly seen than before. The relative refringence of a cord compared with that of the adjacent glass can also be determined at the same time. For ordinary crown glasses chlorobenzol is suggested as an immersion liquid. To lower its refractive index, add benzol; to raise it, add carbon bisulphide or halowax oil.

(415) Preliminary note on monticellite alnoite from Isle Cadieux, Quebec. N. L. Bowen. J. Wash. Acad. Sci., 11, 278–281 (1921).

In this paper monticellite alnoite from Isle Cadieux, Quebec, is described. The rock shows the two olivines, chrysolite and monticellite, the latter usually in greater amount. The chrysolite, together with augite, occurs in early-formed crystals; the monticellite, as well as melilite and biotite, as groundmass minerals that have attacked and resorbed the chrysolite and augite. Monticellite often forms reaction rims around chrysolite that are in optical continuity with it.

Monticellite alnoite is a newly recognized but not a new rock type, for some of the alnoite of the original locality is found to hold monticellite showing the same relationships.

A fuller discussion will appear later in the American Journal of Science.

(418) Note on the determination of the relative expansions of glasses. F. E. Wright. J. Opt. Soc. Amer., 5, 453–460 (1921). (Papers on Optical Glass, No. 36.)

In this paper attention is called to the application of the methods of polarized light to the study of the relative expansion of two glasses. The polarized light employed for this purpose is produced either by reflection from a polished opaque piece of glass at the polarizing angle or by a polarizing prism. The plate under test is examined through a sensitive tint plate and an analyzer sighted toward the polarizer. From the observed change in interference colors the state of radial compression or of radial tension of the glass sample can be inferred, and with it the relative expansion coefficients of the two pieces of glass, or of a piece of glass and an included fragment of glass, of crystallized material, such as a stone, or of a metal wire. The disturbing effects of irregular boundary surfaces can be largely eliminated by immersion of the glass samples in a liquid of the same refractivity.

(419) On tracing rays of light through a reflecting prism with the aid of a meridian projection plot. F. E. Wright. J. Opt. Soc. Amer., 5, 410–419 (1921). (Papers on Optical Glass, No. 37.)

Prisms are used in optical instruments to change the courses of the paths of transmitted rays of light; prisms are of different shapes and sizes and are used either singly or in combination. In many prisms it is difficult to visualize the paths followed by the rays on transmission without graphical aid of some kind. In the present paper the angle meridian projection plot is suggested as suitable for the purpose. Its application to the study of prisms is illustrated by a series of examples from the more common types of reflecting prisms.

(420) The latent heats of fusion of nickel and monel metal. Walter P. White. Chem. and Met. Eng., 25, 17–21 (1921).

By the common method of dropping from a furnace into a calorimeter, the latent heats of nickel and of monel metal have been determined and their specific heats for the intervals to 1360° and 1260°, respectively. The metals were protected against appreciable oxidation by sealing into silica-glass containers. Some improvements were made in the technic of dropping the materials from the furnace into the calorimeter. The precision of the temperature measurement was studied and the results indicate a final accuracy of better than 1 per cent. This indication tends to be confirmed by the agreement of all the determinations but one, which was 1.3 per cent divergent. Several determinations were made by pouring directly into the calorimeter nickel just ready to solidify, giving agreement to about 2 per cent with the furnace results. The latent heat of nickel, 73 calories per gram, is 17 calories greater than the recent determination of Wüst. The latent heat of monel, 68 calories, is in excellent agreement with that of nickel.

(421) Aphthitalite from Kilauea. H. S. Washington and H. E. Merwin. Am. Mineralogist, 6, 121–125 (1921).

This paper describes aphthitalite collected in September 1920 from a hot crack in a recent lava flow of the eruption of 1919–20 of Kilauea. The mineral is uniaxial and rhombohedral, and is compared with occurrences at Etna, Searle's Lake, and elsewhere. Chemical analysis shows that the ratio K_2SO_4: Na_2SO_4 is about 1 : 1.5, like that at Etna, while the ratio at Vesuvius and Searle's Lake is about 3 : 1. It is shown that there is an isodimorphous series from arcanite (K_2SO_4) to thenardite (Na_2SO_4), both crystallographically and optically. The presence of $CuSO_4$ in the mineral is discussed, and the isomorphism of this is indicated. The mode of origin of the mineral is suggested as the oxidation of vaporized sulphides of the alkalies and copper.

(422) Dispersion in optical glasses: III. F. E. Wright. J. Opt. Soc. Amer., 5, 389–397 (1921). (Papers on Optical Glass, No. 38.)

In this paper a reference table of dispersions in optical glasses is given; also a table of differences between the values in the reference table and the corresponding values of the glasses listed by Parra Mantois. The data prove that the chief optical differences in glasses are not differences in the character of the dispersion, but lie in the fact that two glasses may have the same dispersion relations and yet have appreciably different refractive indices. In the dispersion formula both refringence and dispersion should be specifically recognized, the first as a constant establishing a datum level for the refringence and the second as a function of one or more terms expressing the course of dispersion throughout the visible spectrum. These conclusions follow directly from the analysis of the linear relations which have been shown to exist between the partial dispersions of a series of optical glasses. They prove that a rise in the partial dispersion at any part of the spectrum is accompanied by a corresponding rise in partial dispersion over the entire visible spectrum.

(423) The wave-lengths of X-rays. Ralph W. G. Wyckoff. J. Wash. Acad. Sci., 11, 366–373 (1921).

It is shown in this paper that, taking the case of sodium chloride as typical, there are other structures beside the commonly accepted "sodium-chloride arrangement" which are in agreement with the present experimental data. As a result of this lack of definiteness, it is more logical to consider the value of the wave-lengths of X-rays as based upon the quantum hypothesis.

(424) Silica-glass prism for refractometry of liquids at elevated temperatures. F. R. v. Bichowsky and H. E. Merwin. J. Opt. Soc. Amer., 5, 441–443 (1921).

Optically prepared plates of silica-glass were beveled together to form a prism having angles of 45°, 60°, and 75°. The plates were held together in a graphite holder and united by fusing the edges in an oxy-gas flame. The prism was used in an electrically heated goniometer furnace, and the dispersions of sulphuric acid, acetic acid, chloronaphthalene, and sulphur determined at suitable temperatures between 25° and 350°.

(425) Kilauea gases, 1919. E. S. Shepherd. Bull. Hawaiian Volcano Observatory, 9, 83–88 (1921).

Twenty-five samples of gas collected at Kilauea between 1912 and 1919 have been analyzed. The results to date permit the following generalizations:

The major emanation from this volcano is water (H_2O), the average of water in all analyses being about 70 per cent of the total gas evolved. Second in order of magnitude comes carbon dioxide (CO_2), with sulphur dioxide (SO_2) following in third place. Sulphur trioxide (SO_3) occurs in variable amounts, in one instance rising to 5 per cent, whereas in the two samples from Mauna Loa it reached the high value of 8 per cent. Sulphur, while usually small in quantity, sometimes rises as high as 8 per cent.

In general, the 1917 collection, obtained by Shepherd from floating crusts at the lake edge, contains higher amounts of hydrogen (H_2) and carbon monoxide (CO) than the gases of 1918–19 obtained from a variety of sources by Dr. Jaggar. The general inference is, however, that quite regardless of the source from which the gas is obtained, it reaches the surface almost completely burned, or else is actively burning in the surface layer of the lake. Probably both mechanisms obtain.

The ratio of argon to nitrogen is about three times as great as in atmospheric nitrogen. Helium and neon have been positively identified, though the amounts were not notably larger than in residues from air. Chlorine occurs, but in relatively small amount. Whether fluorine is present could not be satisfactorily tested in such volumes of gas as we here dealt with, but there was evidence in the 1912 collection that it was present in about twice the amount of chlorine. Hydrocarbons are apparently absent, or else present in inappreciable quantity.

The water present may well be partly due to oxidation of evolved hydrogen, but such oxidation must occur in the body of the lava lake, presumably near the surface. It does not seem probable that this combination could occur at the actual surface, since any such quantities of hydrogen as would be implied would certainly show marked explosion phenomena. Certainly the highly oxidized condition of these gases, taken as they are from all sorts of promising sources, argues strongly for some such hypothesis as that of Dr. Jaggar, of combustion at or near the lava surface.

(426) The manufacture of optical glass and of optical systems. A war-time problem. F. E. Wright, Lt. Col. Ord. R. C. Ordnance Department Document No. 2037, pp. 309, 94 illustrations (1921). (Papers on Optical Glass, No. 40.)

In this publication, prepared at the request of the War Department, a general account is given of the processes of manufacture of optical glass which were developed in this country during the war. The experience and knowledge necessary to produce optical glass were gained at very considerable expense and largely through the efforts of the Geophysical Laboratory in cooperation with certain manufacturers. The purpose of this report is to make available a small part of the information thus obtained.

The book is divided into seven chapters. Chapter 1 outlines the general situation prior to the war, and includes a brief statement of the war-time production of optical glass. In chapter 2 is given a detailed treatment of the characteristics of optical glass. In chapter 3 the manufacturing processes are considered in detail. Chapter 4 treats of the inspection of optical glass; chapter 5, of the manufacture of lenses and prisms; chapter 6, of the inspection of finished optical parts and of optical systems. Chapter 7 outlines the optical situation during the war; in it a summarized statement is made of the difficulties encountered and of the measures taken to overcome those difficulties. The several factors underlying the general problem of the production of optical munitions during peace and war times are presented in detail, and inferences are drawn regarding suitable methods for meeting the situation adequately.

(427) The crystal structure of alabandite (MnS). Ralph W. G. Wyckoff. Am. J. Sci., 2, 239–249 (1921).

By a combination of a reflection spectrum from a known crystal face with a powder reflection, and employing the general method based upon the theory of space groups, it is shown that the arrangement of the atoms in alabandite is either that of the "sodium-chloride grouping" or is a grouping approaching very close to this arrangement.

PRELIMINARY REPORT OF ADVISORY COMMITTEE IN SEISMOLOGY.

The proposal of the Carnegie Institution of Washington to enter the field of seismology has the approval of the Advisory Committee in Seismology for several important and, in the opinion of the committee, opportune reasons.

(1) This country has not hitherto taken an active part in seismologic research when compared, for example, with England, Germany, or Japan.

(2) In the State of California there is probably a more favorable opportunity for the study of crustal movements in great variety than in any other region, save possibly Japan. Furthermore, if the landslips there are due in whole or in part to accumulating stresses caused by crustal drift or otherwise, then the present is a more opportune time for their study than the period immediately following a release of these stresses (earthquake).

(3) As research is organized in the United States, a reasonably comprehensive study of California earth movements would require the participation of several agencies which would probably not undertake the task independently, but which have indicated a desire to cooperate with the Carnegie Institution in such a study. It is of interest to note that, since the action of the Institution became known, resolutions of indorsement and support have been passed by the San Francisco section of the American Institute of Mining Engineers (May 17), by the Board of Directors of the Seismological Society of America (May 25), by the Executive Committee of the American Geophysical Union (September 17), and by the Commonwealth Club of San Francisco (November 17).

(4) Studies of local movements as opposed to teleseismic observations have not been systematically undertaken hitherto (except to some extent in Japan). They appear to offer a fertile field of research and to promise information of considerable economic value, particularly to the West Coast region of the United States.

There is already in existence a rather carefully prepared plan[1] for the study of earth movements in California, which has had the approval and indorsement of the American Geophysical Union and of the Division of Geology and Geography of the National Research Council. It has been published and has received some favorable individual comment.

Assuming that the Institution is favorably disposed toward taking the initiative in such an undertaking, your committee is of the opinion that there are five different projects which might profitably receive attention together. These will be stated briefly in succession:

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[1] H. O. Wood: "The earthquake problem in the western United States," Bull. Seis. Soc. Am., VI, 4, Dec. 1916.

1. Study of Geological Formation along the California Fault-Lines.

This problem has received consideration, both before and since the great San Francisco earthquake in 1906, but for various reasons our knowledge is still inadequate in the fault zones. It will be most effectively performed by the United States Geological Survey with the cooperation of the Departments of Geology at the California universities. The plan should include a detailed map of the line of the San Andreas rift with measured displacements, as well as special geologic examinations and maps of other significant localities.

In carrying out this plan the attempt should be made to determine not only the surface formations in which effects of displacement are visible but, in so far as there are available exposures, to ascertain the character of the formations at considerable depths. The recent field observations undertaken by the Geological Department of Stanford University will contribute to this latter purpose, and it is understood that these studies will be continued as opportunity may offer.

2. Surface Displacements.

Following the great San Francisco earthquake in 1906, the United States Coast and Geodetic Survey reoccupied its earlier stations in the vicinity of the San Andreas fault and determined, by reference to the Mocho-Diablo base-line, a number of displacements on both sides of the rift. No determination was made of the stability of the base-line itself, although it lies within the zone of movement.

More recently, both the Ukiah and Lick Observatories have reported indications of a northward drift of those stations. The order of magnitude of this drift as reported by Ukiah amounts to 0.3 meter per year. The latitude of Mount Hamilton as determined from meridian-circle observations for the accurate positions of stars showed a northerly drift in the period 1893–1915, but with a strong set-back at about the time of the severe earthquake of August 3, 1903. The Mocho-Diablo line lies substantially between these two stations.

It should also be noted in this connection that the observations of the Coast and Geodetic Survey made in 1907 establish positions as of the period immediately following the earthquake, i. e., after the accumulated strains which may have caused the slip had been released. Similarly, the earlier triangulation measurements were affected in a manner not now determinable, by the earthquake of 1868. It is very likely, therefore, that the comparative measurements of record, thus far, yield incomplete information concerning either the direction or magnitude of crustal strains to which these slips were due, although the magnitude of the slips themselves has been measured in several localities.

In the opinion of the Committee, therefore, it is a matter of considerable importance to invite the United States Coast and Geodetic Survey to continue these measurements and, if practicable, to extend them before another considerable slip occurs. It is also of the first importance to carry the system of primary triangulation and precise levels across the mountains to a region of unquestioned stability. This organization alone possesses the requisite equipment and trained personnel for this work.

3. Southern California.

We have in southern California a region of intricate faulting, in which many of the faults are still active. Nevertheless, there is no primary triangulation in this region through which the magnitude and displacement of the land-slips which occur there can be determined.

The plan prepared by Mr. H. O. Wood and printed in the Journal of Seismology, to which reference has been made above, is concerned primarily with studies in this region and the opportunity here open for the systematic study of seismic disturbances has been adequately emphasized. The reasons for selecting this region for detailed study need not be repeated here. Mr. Wood's plan is elaborate beyond any resources now available for its prosecution, but your Committee recommends that, as soon as suitable instruments are available, a beginning be made of continuous seismologic observations at selected points in this region for the study of local earth movements, both tremors and displacements.

4. Development of Instruments.

It happens that no instrument appropriate for recording local earthquakes of short period and locating of their sources has yet been developed, although instruments for recording of shocks of distant origin have been in continuous operation at many stations for a number of years. It also happens that one of the necessities of war promoted the development of a receiving instrument for vibrations of extremely short period through water (the supersonic experiments). Somewhere between these two systems there is required an instrument of considerable elasticity through which to record local vibrations of intermediate period, such as are found in the California region and in the countries where volcanism is active.

Your committee is of the opinion that for the study of local earth movements it is indispensable that appropriate agencies be invited to take up this instrument problem as soon as practicable. It also appears desirable that more than one type of instrument be considered in view of the considerable variety in the character of the shocks to be studied and the great variation in amplitude to be expected.

5. Isostasy.

Your committee is of the opinion that the gravity observations of the Coast Survey should be continued in connection with the observations of crustal displacement, particularly in view of the immense differences in land elevation in California and also of density between the mountains and the foot of the deep-sea fault off the West Coast. The changes in elevation are so abrupt and the densities hitherto measured (both by laboratory determination and by the field pendulum) so variable as to furnish a remarkable opportunity for application of the theory of isostatic adjustment.

These five studies together constitute a comprehensive approach to a discussion of crustal movement of a magnitude and scope beyond anything hitherto attempted, and for which California offers an unparalleled opportunity. To carry out a plan of this magnitude no single agency is adequate.

It is, therefore, recommended that the Carnegie Institution invite:

(1) The cooperation of the U. S. Coast and Geodetic Survey to undertake:

(*a*) A system of primary triangulation and precise levels, (1) in the San Francisco region connecting with a permanent base east of the mountains (Reno), (2) southward along the fault zone to include the region of complex faulting in the vicinity of Los Angeles, (3) thence eastward to connect with an appropriate zone of no movement east of the mountains.

(*b*) The establishment at suitable localities of new lines of monuments at right angles to the San Andreas fault, the San Jacinto fault, and perhaps others, for the purpose of measuring displacements there.

(*c*) To continue its pendulum and plumb-line observations in close cooperation with the work above outlined.

*(*d*) To make a series of deep-sea soundings north and south from Monterey Bay to determine the direction and height of the fault scarp forming the termination of the continental shelf in that region.

(2) The cooperation of the United States Geological Survey to determine geological relations in the California fault areas.

(3) The cooperation of the California Institute of Technology, the Mount Wilson Observatory, and other agencies, if necessary, in the development of seismometric recording apparatus for study of local tremors.

(4) The cooperation of the Lick Observatory and the Ukiah Observatory for the continuation of their observations of crustal drift. At the Lick Observatory it is particularly recommended that a suitable special instrument be provided for this purpose.

It is recommended further that the present Research Associate of the Institution, Mr. H. O. Wood, be continued in the field in southern California to gather such information from local sources as will facilitate the location of the instruments referred to in paragraph 3 above and the appropriate triangulation stations for the discovery of displacements in the fault zone in that region.

ANDERSON, J. A.,
ARNOLD, RALPH,
CAMPBELL, W. W.,
DAY, ARTHUR L. (Chairman),
LAWSON, A. C.,
MILLIKAN, R. A.,
REID, HARRY FIELDING,
WILLIS, BAILEY,
Advisory Committee in Seismology.

CARNEGIE INSTITUTION OF WASHINGTON,
October 1921.

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*Willis dissenting.

DEPARTMENT OF HISTORICAL RESEARCH.[1]

J. FRANKLIN JAMESON, DIRECTOR.

The following report, the sixteenth annual report submitted by the present Director, covers the period of eleven months extending from October 1, 1920, to August 31, 1921.

In the staff of the Department there was, at the beginning of the year reported upon, a vacancy due to the resignation, in the preceding August, of Miss Esther Galbraith. In January that vacancy was filled by the accession of Miss Shirley Farr, formerly an instructor in the University of Chicago. Miss Louisa F. Washington, who since the autumn of 1918 had been the stenographer of the Department, resigned that position at the beginning of April, after nearly three years of most faithful and efficient service. During April, May, and the first half of June, Mr. Jesse A. Langley occupied that position. In view of the absence of the Director in Europe, it was not thought necessary to fill it during the summer. From November on, it will be filled by Mrs. Louise F. Pierce.

On June 24 the Director sailed for England, upon an absence which continued till the end of the year reported upon and of which the chief object was the collecting of materials and the making of arrangements for the proposed volumes of the Correspondence of the British Ministers in Washington, an undertaking described at a later point in this report. There were also subsidiary objects, which led to a brief visit, at the end of July and in the early days of August, to several towns and persons in Belgium and the Netherlands, and will cause journeys to Paris and to the three chief archives of Spain, those of Simancas, Madrid, and Seville, before the return to America. From July 11 to July 16, the Director was occupied with attendance upon the sessions of an Anglo-American Conference of Professors of History, called by the University of London upon the occasion of the opening of its new Institute of Historical Research, and intended for the consideration of problems of historical research and publication rather than of class-room instruction. He also attended, as a corresponding member, sessions of the British Academy and of the Classe des Lettres in the Académie Royale de Belgique.

Several persons outside the regular staff of the Department have during the year given important and valued assistance to its work. In November and December Professor Marcus W. Jernegan, of the University of Chicago, known as an authoritative student of the earlier history of education and religion in America, devoted some weeks to the intricate and difficult work of preparing, in concert with Dr. Paullin, those maps in the Atlas of the Historical Geography of the United States which will illustrate educational and religious history by exhibiting the situation of colleges and churches at different periods.

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[1] Address No. 1140 Woodward Building, Washington, D. C.

Professor John S. Bassett, of Smith College, in continuation of his work, described in the last report of the Department, upon the Correspondence of Andrew Jackson, was able to devote some time to that collection during the academic year, and the short vacations, and the whole of August (and, to anticipate, most of September). At the end of July he made a thorough search of the Nashville region for additional materials, and then came to Washington for several weeks of work in the arranging and annotation of the letters already copied in the Jackson Collection possessed by the Library of Congress. Miss Jane Boyd continued the work of transcription from November to July, and Professor W. J. Seelye assisted in collation.

Others outside the regular staff who assisted the work of the Department during the year were Miss Elizabeth Donnan, formerly a member of the Department, but now assistant professor in Wellesley College; Mrs. N. M. Miller Surrey, of New York City; Professor Herbert C. Bell, of Bowdoin College; Mr. Abel Doysié, of Paris; Mrs. R. C. H. Catterall; and Mr. David M. Matteson, of Cambridge. The work done by each is described in its appropriate place below.

As in previous years, acknowledgment is cordially made of the favors constantly shown to the Department, with the greatest liberality, by the officials of the Library of Congress, and especially by Dr. Herbert Putnam, the librarian; by Mr. A. P. C. Griffin, chief assistant librarian; by Mr. Charles Moore, chief of the Manuscripts Division; and by Mr. P. Lee Phillips, chief of the Map Division. Grateful recognition is also made of the courtesy shown by the New York Public Library in facilitating the work of Mrs. Surrey. The Director wishes also to express his thanks to the authorities of the British Museum and the Public Record Office, especially Dr. Hubert Hall, and to librarians and archivists in Ghent, the Hague, and Middelburg. At the same time, no American student of history is likely to return without a heightened appreciation of the advantages he enjoys in the Library of Congress and other American libraries by reason of the longer hours, the greater freedom, and the excellent mechanical facilities.

REPORTS, AIDS, AND GUIDES.

The "Guide to Materials for American History in Paris Archives," upon which Mr. Leland has long been engaged, has been considerably advanced during the year and has been brought to the point where he can profitably go again to Paris, in the next spring, to bring it to completion. All gaps left in his notes when his work there was interrupted by the advent of war in 1914 have been noted and arrangements made for their systematic filling. In course of this preparation, Mr. Leland has partly gone through the Stevens Catalogue in the Library of Congress, Stevens's Facsimiles, and the groups of papers there known as the Peace Transcripts and the French Alliance Transcripts. He hopes to complete whatever examination of them necessary for his purpose before sailing, so as to have his notes on the Foreign Office material for the period from 1765 to 1783 in their final form.

Meanwhile Mr. Doysié, from September 1, 1920, to July 15, 1921, has examined about 450 volumes, cartons, or portfolios in the French archives. In the archives of the Ministry of Foreign Affairs, the series "Spain" has been completed and the series "England" nearly completed. These two series are, apart from the various series devoted specifically to America, the most important for our purposes in the Foreign Office because of the American material which is to be found in nearly every volume. Their examination has, therefore, been made with great care and in considerable detail. In the Dépôt des Cartes et Plans de la Marine (Hydrographic Service) the series of volumes and cartons in the "Grandes Archives" has been completed and the examination of the series of portfolios containing maps has been carried well toward conclusion. A large number of American documents and maps, many of them of capital importance, have been found in this depository, which had never before been examined from the point of view of American history. A notable illustration is furnished by the journal of a French emissary sent to traverse the British colonies in 1765 to observe their state of mind, their spirit of opposition to British measures of control, and their defenses. The journal is of especial interest because it contains the only contemporary account by an eye-witness of Patrick Henry's famous speech on the Stamp Act, in the House of Burgesses, May 30, 1765. The journal has been printed in the *American Historical Review* for July and October, 1921.

In the archives of the Ministry of the Colonies, now deposited in the Archives Nationales, some twenty or thirty volumes of the "Correspondance Générale, St. Domingue" (series C 9), have been reexamined. In the archives of the Ministry of Marine, in the same place of deposit, a substantial beginning has been made in the examination of the most important series of the "Modern Archives" (those for the period since 1789), series BB 4, "Campagnes," a series which consists mainly of reports, despatches, etc., from officers on board ships of war. It has been examined through volume 273 (1808). Many documents have been described, relating to combats between French and British vessels in American waters, to combats between French and American vessels in 1800, to naval operations generally in American waters, to convoys and supplies from the United States, to the slave-trade, to the French expedition to retake possession of Louisiana, and like topics.

Mr. Leland's plan is, after arriving in Paris, to devote all his time to completing the manuscript of the first of the three volumes of which the Guide will be composed, the volume relating to manuscripts in the libraries of Paris; then to complete the second volume, relating chiefly to the Archives Nationales; and finally the third, relating to the archives of those ministries which have not yet deposited their papers in the Archives Nationales.

The work upon which Mrs. Surrey has been engaged, the making of a catalogue of Documents in Paris Archives relating to the History of the Mississippi Valley, is in practice an adjunct to the work of Mr. Leland and Mr. Doysié reported upon in the preceding paragraphs, though it has a separate history and origin. That history has been recounted in previous reports, but needs to be borne in mind, since only in the light of that history can one explain the reasons for selecting, for fuller treatment by way of catalogue, one portion of the larger field covered by the researches in Paris of Mr. Leland and Mr. Doysié. During the year Mrs. Surrey has written 4,047 cards from the notes taken by those gentlemen, making a total, thus far, of 24,308 cards. She has now dealt with all the material in the archives of the Ministry of Foreign Affairs and with most of that in the Ministries of the Marine and of the Colonies. This leaves, as yet to be done, the lesser groups of documents in the Bibliothèque Nationale and the minor libraries, in the Ministry of War, and in the Archives Nationales. Mrs. Surrey spent about a month in Washington in the spring, going over with Mr. Leland the notes which she has not yet dealt with, and will be able to proceed with these in his absence, and with those which he or Mr. Doysié may in addition make during the coming year. Meantime it is not impossible for historical scholars to make some use of the catalogue, though still in process of compilation, and this has been done, in two important instances, during the past year.

Mr. Van Laer's state of health, and the engrossing duties of his position as archivist of the State of New York, have not permitted him to finish the manuscript of his report on the materials for American history in the archives of the Netherlands, for which the needful notes were taken during the expedition which he made to those archives, on behalf of the Institution, in the spring of 1919. Some progress has, however, been made, and more is likely to be made in the month immediately succeeding the date of this report.

Professor Bell, spending the summer in London, has resumed the work in the Public Record Office upon which he spent the summer of 1919, the work, namely, of preparing a fuller description than has heretofore been given of the West Indian section of the Colonial Office Papers, to be combined later with a full inventory of the archives of the West Indian Islands themselves, these two classes of papers being mutually complementary and both alike necessary to a proper understanding of the history of that British colonial empire of which the Thirteen Colonies formed only a part.

Mr. Bell, during that portion of the summer which he spent in the work of the Department, completed all branches of his survey of the West Indian papers to the year 1775. From that point on, the inventory, which it is proposed to carry to 1815, should properly take on a different character, calling for a somewhat different procedure. The reasons for making a guide to the West Indian papers of the period before 1775 are two: First, a proper understanding of the British colonial empire of that period requires that it, or at any rate its American portion, be studied as a whole, both as regards the imperial administration, acting on all colonies alike, and as regards the constitutional history of the colonies themselves, in whose forms and methods of government types prevailed which can not be rightly understood without taking into consideration all representatives or instances of those types. In the second place, the colonies of the mainland had constant relations with the island colonies, especially in the way of commerce; indeed, in the commercial history of the continental colonies there is hardly any chapter more important than that of their West Indian trade. Now, from the beginning of American independence the first of these reasons, on the whole, falls away. The United States enter upon a constitutional evolution, in federal and state forms, in which the West Indian colonies of Great Britain have no share and on which they exert no appreciable influence. The interest of the West Indian papers of the period from 1775 to 1815 lies in the contacts—military, naval, and commercial—between the United States, or American citizens, and the colonies of a foreign power, with which the United States was involved in two wars during the period named, one occupying the first eight of these years, the other the last two, while the years between, 1783-1812, were full of commercial conflict and friction, owing to the policy maintained by Great Britain in the matter of commerce with her colonies. For the years 1775 to 1815, accordingly, the compiler of this inventory is expected to take note of those papers only which have a relation to the United States or its citizens—documents relating to military measures, naval operations or vessels, privateers and prizes, seizures, impressments, customs, matters of commerce and navigation, and the like.

Mr. Bell, unable to devote the whole summer to work for the Department, and obliged in any case to return in September for the academic year at Bowdoin College, has spent the latter part of his London time in instructing a successor in the treatment of the documents of this later period and in supervising the beginnings of her work. Miss Lillian Penson, of the University of London, already an accomplished student of West Indian history, has been engaged to perform this service for the Department. When this search is completed, the proposed volume—since reports on the archives of Jamaica, Bermuda, and the Bahamas are already in hand—will lack only the examination of such archives as are preserved in the Lesser British Antilles.

Mr. Bell has also been able to make for the Department, in Dublin, a summary report upon the materials for American history which are to be found in the Public Record Office of Ireland. The amount of such material to be found there is, as the Director of the Department was convinced by a hasty reconnaissance in 1913, not great. It is mostly commercial; on the important subject of Irish emigration to the American colonies and the United States little light is cast. It is expected that Mr. Bell's brief report will be amplified on at least one side, that of prize and other admiralty records, by searches made at more leisure by a worker resident in Dublin. In the archives of Edinburgh, Miss Sibyl Norman has found a certain number of documents of interest to students of American history. She has not yet been able to carry out the search systematically or thoroughly, but it is not believed that many such documents are to be found.

In the work upon the "Atlas of the Historical Geography of the United States," Dr. Paullin has made progress along five lines. First he has completed the series "Lands," which as finished consists of 61 maps and 30 pages of text; the principal matters illustrated are: divisions of the land, disposition of the land by the government, and varieties of land-holding. Secondly, in the series illustrating transportation, for which the later maps had already been made by Dr. Paullin and Professor Whitbeck, the former has now completed four maps showing the main stage-coach roads and the public post-roads of 1774, the main post-roads of 1804 and 1834, and the railroads of 1870. Thirdly, he has completed five maps illustrating colleges, at various periods from 1775 to 1890, and nineteen maps illustrating churches in 1860 and 1890, and has assisted Professor Jernegan in preparations for the series illustrating the churches in 1775. Fourthly, he has begun work on three maps designed to show the routes of French, Spanish, and American explorers in the Mississippi and trans-Mississippi regions. Finally, he has begun the work of bringing certain series up to date by the addition of maps for which materials have, by the lapse of time, become now available. These include maps showing the geographical distribution of votes in Congress on the war resolution of 1917 and of popular votes in the presidential election of 1920, and various maps resting on the data collected in the census of 1920, and completing series resting on earlier censuses. For all maps that have been completed, the letterpress has also been prepared. In the execution of the maps Dr. Paullin has had, as usual, the aid of Mr. J. B. Bronson as draftsman.

Mr. Matteson's work on the items respecting manuscripts relating to American history which are to be found in the printed catalogues of manuscripts put forth by European libraries, or otherwise published, was continued during the last three months of 1920, but not during 1921. His searches, in the portion of time which he gave to our work, covered the catalogue material to be found in the New York Public Library and the libraries of Columbia University and Yale University, from which some additions were made to the titles he had accumulated by the work pursued hitherto in the libraries of Cambridge and Boston.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

Miss Davenport has made ready for publication six more treaties, 1670–1675, for the second volume of her "European Treaties bearing on the history of the United States." She has also worked on the next group, the treaties of 1678–1680, but these are so connected one with another, and in general the diplomatic history of the negotiations against and with Louis XIV is so intricate, that it is difficult to regard work upon any one of the group as finished until all are finished.

Dr. Burnett has continued work upon the annotation of the later volumes of his "Letters of Members of the Continental Congress," while seeing volume I through the press. The latter process was delayed by the Director's decision that there ought to be prefixed to each volume an exhibit, as complete as could be made, of the elections to membership in the Congress by the respective States and of the dates of attendance of the individual members. The state of the existing materials for such a conspectus made the composition of it a slow process, but it will unquestionably be helpful to readers. The making of a full preface to volume I, intended as a preface to the whole series, and the making of the index, which was prepared by Mr. Matteson, also took time, but the volume was published in August. It is a book of 638 pages, embracing 762 letters, or relevant parts of letters, written by members of the Continental Congress from the seat of its sessions, from its commencement in September 1774 to July 4, 1776, inclusive. A few later letters and documents casting light on mooted questions respecting the signing of the Declaration of Independence are added as an appendix.

The plan of this work was described in a previous report, several years ago. It may here suffice to mention that, since the Continental Congress sat with closed doors, no formal or official record of its debates exists, nor any formal record of its proceedings except the official journal kept by its secretary, Charles Thomson, which was not written with the fulness demanded in our time of a legislative journal. Therefore, for the debates and for many transactions our only sources of information, aside from the few diaries which members kept, chiefly in the earliest days of the Congress, are the letters which they wrote during the time of their attendance upon Congress to the governors or other chief authorities of their States, or to relatives and friends at home, and in which, in spite of their collective votes of secrecy, they individually conveyed a great amount of information as to what was going on. The extent of that information was not suspected when the work began. Its collection was a labor of some years, in the course of which all the capitals and chief historical societies of the thirteen original States were visited and copies were secured of all letters falling within the scheme of the proposed publication. Also, many private possessors of letters generously permitted their use, or the use of the parts desired—for it should be remarked that, voluminous as the work is, it includes only those parts of letters (or diaries or notes) which give actual information about the doings of Congress additional to that which is contained in the published *Journals*. The Library of Congress is reprinting those journals, or rather printing them completely for the first time; Dr. Burnett's work is in the strictest sense complementary to that of the Library. At the same time, it should also be remarked that he has not omitted letters because they have been printed before, for the value and usefulness of his compilation depend largely upon the cumulative effect obtained by bringing together all the material, written by delegates of whatever State or from whatever point of view, that illustrates the transactions of a body having so little homogeneity as the Continental Congress. Indeed, the first volume is mainly made up of letters which have been printed before, but in widely scattered and sometimes uncommon books, and now printed with more exactitude of text and brought together into mutual illustration and support. It is chiefly for this earlier period (from September 1774 to July 4, 1776) that letters of members have been already printed, for the attention of historical inquirers has been much concentrated on those months; later volumes will consist mainly of material hitherto unknown.

The manuscript of volume II of this work was ready to be presented to the Institution at the date with which this report is concluded. The third and fourth volumes are nearly ready, and the fifth and sixth, completing the series, can be made ready without great delay, for, from the method of procedure necessarily followed in the gathering of the material, the texts for all six were in hand before the process of annotation was begun. As new occasions, such as auction sales or fresh accessions by historical societies, bring to light additional letters whose dates fall within the limits of the earlier volumes, they are copied and the copies preserved against the issue of the sixth volume, in which they will be included in an appendix.

In the series which is being prepared by Dr. Stock, "Proceedings and Debates of Parliament respecting North America," the work at present going on is that of annotating the texts, gathered together long since. During the year Dr. Stock has carried this work of annotation from 1645 to 1667. The first volume, therefore, which will end either with the year 1689 or with 1700, is nearing completion. Meanwhile, the Director's sojourn in London is giving some opportunities for the obtaining of additional material, in the way of records of debates in the eighteenth century. It should be remarked that the scope of the publication embraces the Scottish and Irish parliaments, as well as those of Great Britain.

Miss Donnan, returning temporarily to the work of the Department, has devoted the summer to investigations intended to complete the work on which she was engaged when she resigned from the staff, the making of a collection of documents and narratives illustrating the history of the African slave-trade and the importation of slaves into English America, primarily the importation into the mainland colonies. The main lack, when the work was interrupted, was the inspection of the manuscript materials in England. She has spent the past summer in London in that research, chiefly at the Public Record Office, but partly in the British Museum. At the end of her stay in England a visit was made to Bristol, where in the eighteenth century many merchants were engaged in the trade and where a considerable amount of material respecting it still exists. In the Public Record Office the main collection to be examined was the papers of the Royal African Company. It is a collection of enormous extent (some 2,000 volumes), and its examination would have been almost hopeless but for the fact that the Department some years ago had secured a systematic report upon its subdivisions and contents from the competent hands of Mr. A. Percival Newton, now professor of imperial and colonial history in the University of London, and who, together with some of his special students, was most helpful on the present occasion. Out of these various sources, but especially from this last-named collection, which extends from 1662 to 1822, Miss Donnan secured a rich store of documents for her volumes.

Mrs. Catterall, resuming work upon restoration of health, has carried her examination of judicial reports of slave cases, condensation of judicial opinions, and excerpting of narratives, through the reports of South Carolina and Kentucky, and some way into the series of Virginia Reports.

The Correspondence of Andrew Jackson, under the editorial care of Professor Bassett, has been all copied and collated down to the following dates: the letters of Jackson from 1788 to 1845 (the whole mass), and the letters to Jackson, of which a smaller number are to be printed, from 1788 to March 4, 1829, representing about two-thirds of the whole.

The Director's main object in going to England for the summer was to prepare the way for still another documentary publication which he hopes in time to achieve, a series of volumes of the Correspondence of the British Ministers in Washington. It is thought certain that, in the next series of years, American historical scholars will devote increased attention to the diplomatic history of the United States, in which our relations with Great Britain must always have the foremost place. It is conceived, moreover, that such a publication as is proposed may well be productive of much good outside the limited ranks of the historical profession. Without exaggerating in the least the extent to which volumes of documents are read by the general public, or filter to it through the minds of historians, it is quite possible to believe that a full publication of the instructions which British Secretaries for Foreign Affairs sent to the representatives of their government in Washington, and of the answering despatches in which the ministers conveyed the information on which in large part those instructions were based, may do a salutary work in substituting in the public mind, or at the least some part of it, a real knowledge of the actual nature and course of British policy toward the United States, for surmise and suspicion as to the "deep and dark designs" of Downing Street. Whether British policy toward the United States in earlier times were good or evil, or a mixture of both, knowledge and actual fact are better than imagination and legend, and the substitution, so far as it can be effected, may do something to clarify future relations. Moreover, such a publication as is proposed is not likely to be undertaken by any one else. The correspondence which passed between the American Secretary of State and the American minister in London, and also that which passed between the latter and the British Foreign Secretary and that which passed between the American Secretary of State and the British minister in Washington, are matters which the United States government may appropriately publish, and of which, indeed, it has in past times published a large part; but it would not be within its proper functions to print the correspondence of the British minister with his chief in London or with the governor-general of Canada or other British subjects, and the British government is known to have no intention of doing so. Mr. Balfour, however, when Foreign Secretary, expressed entire willingness that the volumes of correspondence preserved among the Foreign Office Papers at the Public Record Office should be used for the purpose indicated, and it is not apprehended that any subsequent secretary would be likely to take a different view.

The American series in the Foreign Office Papers will undoubtedly supply the main substance of the proposed publication, and will present no other difficulties than such as arise from their great extent, which must be provided against by suitable compression. But in many cases, and sometimes systematically, ministers wrote private letters to their chief, in which they often expressed themselves more freely and more interestingly than in the official series of despatches. These letters did not usually go into the official files of the Foreign Office, but remained in the possession of the Secretary, who took them with him when he went out of office—though several groups of them have in modern times come back into the possession of the public and are now in the Public Record Office. Since such correspondence, when it can be found, or that which ministers maintained with friends or relatives in Great Britain, is often more illuminating than the official despatches, it seemed a duty to hunt for it, and secure copies of what might be available.

The results of the expedition in this particular respect, up to the date at which this report ends, have been meager. Everyone has been most obliging, but it does not appear that, with one important exception, much correspondence of the earlier ministers in Washington is extant in private hands. That exception consists of the abundant papers of Sir Charles Bagot, who admirably represented Great Britain in Washington from 1816 to 1819, and, as the first minister after the war of 1812, did much to smooth over ruffled surfaces and prepare the way for permanent peace. Copies of many of his papers of that period, and some originals, are in Ottawa, in the Public Archives of Canada, and the Director had the opportunity to examine them there in November, through the kindness of Dr. Arthur G. Doughty, C. M. G., public archivist, and of Mr. David M. Parker, keeper of the manuscript room, formerly a member of the staff of this Department. But the main store of the originals, outside the Public Record Office, is in the possession of Sir Charles Bagot's heir, Richard Bagot esq., of Levens Hall, by whose kindness the Director was offered the fullest opportunity to make use of these interesting manuscripts.

Besides collections in the hands of descendants of diplomatic ministers, other sources would be those which have come down from foreign secretaries of the time—the period before 1830—to which the present search was limited. During the greater number of the years from 1791, when the first minister to the United States was appointed, to 1830, three men occupied that position—Lord Grenville, George Canning, and Lord Castlereagh. Grenville's very numerous papers, now in the possession of Mr. J. B. Fortescue of Dropmore, have mostly been printed by the Historical Manuscripts Commission, and though Mr. Fortescue very obligingly sent to the Public Record Office, for the Director's use, the portfolios thought to be relevant, they contained no letters of British ministers in Washington or Philadelphia additional to those printed by the commission named. Lord Lascelles kindly gave permission to examine at Chesterfield House such papers of Canning as are in the possession of the family. That collection, which the Director was apparently the first historical scholar to examine, is but the surviving portion, though an important and valuable one, of the whole mass of Canning's papers; it contains only a few letters germane to the present purpose, but those (letters from Canning's intimate friend Charles Bagot and from his cousin Stratford Canning) are interesting.

Lord Londonderry has expressed similar willingness to aid, in the matter of Castlereagh's papers, but his duties as a member of the Cabinet of Ulster, exacting duties at the present time, have up to the date of this report prevented action on his part. Correspondence, of the sort desired, coming down from those who held the office of Foreign Secretary during briefer portions of the period contemplated, seems not to be extant, except that some of Wellesley's is in the manuscript department of the British Museum.

On the other hand, two important collections of the private papers of men who were British ministers in Washington have been presented by their heirs to the Public Record Office and are rich in material for our purpose. They are those of Francis James Jackson, minister from 1807 to 1809, and of Stratford Canning, minister from 1820 to

1823, afterward Lord Stratford de Redcliffe, the famous ambassador in Constantinople. Only a few letters from these collections have been printed. Finally, the numerous papers of Sir Charles R. Vaughan, minister 1825–1835, are in the library of All Souls College, Oxford, where by the kindness of the Warden and the librarian, Professor (Sir) Charles Oman, M. P., a beginning of their examination has been made. It will be seen that the main source of material will be the Public Record Office.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff. The American Historical Association and various other historical organizations have received such aid as could appropriately be rendered in respect to investigations in Washington and other services, and many queries from individuals have been answered, or transcripts of documents procured for them. Mr. Leland and the Director have done what they could to promote the measure for the erection in Washington of a suitable National Archive Building, for which an appropriation was so nearly secured in the last session of Congress. All the staff exerted themselves, in various ways, to make successful the annual meeting of the American Historical Association in December, which this year was held in Washington.

The Director has served as one of the two representatives of that association in the American Council of Learned Societies, and as a member of the committee of ways and means in that council. Mr. Leland has served the Council in the preparation and issue of its periodical Bulletin, and the Association in a wide variety of ways, and has continued to direct the work of transcribing documents in Parisian archives for the Library of Congress. He has written a brief history of the work of the National Board for Historical Service, for insertion in the *Annual Report* of the American Historical Association, and is preparing, for Professor Shotwell's series of volumes on the economic and social history of the Great War—a series conducted under the auspices of the Carnegie Endowment for International Peace—a monograph on the war archives of the United States. Dr. Stock has given courses of historical instruction in the Catholic University of America.

As to the Bandelier collection of documents obtained in Spain and relating to the Pueblo Indians and the history of the Rio Grande region, Professor Charles W. Hackett, of the University of Texas, to whom the editing of that material has been confided, reports that he has spent the whole summer in the work and has nearly completed the manuscript of the first volume. This volume—Spanish texts and accompanying English translations, introductions, and annotations—will apparently be received from him this winter. It will make a notable contribution to our knowledge of the field involved.

DEPARTMENT OF MARINE BIOLOGY.[1]

ALFRED G. MAYOR, DIRECTOR.

In February 1921, Professor E. Newton Harvey returned from an expedition to the island of Banda, Dutch East Indies, whither he had gone to study the chemical and physiological nature of the light emitted from the dorsal region of the head in two species of fish. This light is so brilliant that fishermen use these fishes as a lure when fishing at night. Professor Harvey found that this light is due to the presence of symbiotic bacteria which live in a large gland in the head of the fish, and is not caused by a reaction between luciferin and luciferase. He hoped to discover a source from which large supplies of luciferin and luciferase might be obtained for analysis, but at present the minute *Cypridina hilgendorfi* of Japan remains the most available known source of these substances among marine animals.

During the winter chemical analyses of samples of the ancient barrier reef of Tutuila, Samoa, were made for the Director by Professor Alexander H. Phillips. The top of this dead reef is now submerged about 180 feet below present sea-level, thus too deep for the growth of reef corals. Fragments of this old reef which once encircled Tutuila have, however, been tossed up and embedded in the tuff cone of Aunuu Island, which lies off the southeast shore of Tutuila and also in the tuff crater at Fagulua, near Stepps Point, on the south shore of Tutuila. In these specimens the $CaCO_3$ ranged from 97.2 to 98.3 per cent and the $MgCO_3$ from 1.06 to 1.65, thus being comparable in these respects with reef rock, and showing no evidence of dolomitization, such as was suddenly encountered in the boring at Funafuti at depths below 637 feet. This discovery of an ancient dolomitized mass of limestone at depths below 637 feet at Funafuti has, of course, no general bearing, for no attempts have been made to bore into the atolls of groups other than the Ellice Islands, but such borings might easily be made in the Paumotus, Marshall, and Fiji groups, and they might throw much light on the problem of the relationship between modern and ancient coral reefs in the Pacific. Such borings will of course never be made for commercial purposes and must be carried out purely for their scientific interest.

As was previously reported, on September 9–10, 1919, serious damage was done to the Tortugas laboratory by one of the most severe hurricanes recorded from the Florida region. The wind blew up great masses of sand from the beaches, and this sand was even driven in through the broken panes of glass at the top of the lighthouse, 158 feet above sea-level; it scoured the paint off our wooden buildings, while fragments of wood and trees were driven through half-inch planks in a number of places. Our windmill and one laboratory building were wholly destroyed, as were also the lower part of the kitchen and dining-room, where the waves dashed through them, and minor damage was done to the dock and other structures. Due to the high cost of materials and labor, and the practical impossibility of obtaining an adequate supply of building materials, it was decided to defer making permanent repairs until this year.

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[1] Situated at Tortugas, Florida.

Due to the necessity of keeping our men at work on these repairs to the laboratory, it was deemed inadvisable to invite many investigators to study at Tortugas this summer, and accordingly only a few who had been there in past years and whose researches required extension or completion came to Tortugas. Our force, thus freed from other duties, was enabled to complete the restoration of the laboratory, aquarium, windmill, and dock-houses; so the station will be in as good form as ever for the reception of investigators in 1922.

Perhaps the most serious damage done by the hurricane was the destruction of a considerable length of the brick sea-wall of the moat surrounding Fort Jefferson. This moat, with its semi-stagnant water, was the source of our supply of *Cassiopea* and other animals used so extensively in our physiological researches, and when the wall was destroyed pure sea-water entered the moat and these creatures have, in consequence, disappeared. This loss, should it be permanent, would probably force us to abandon the laboratory. The fort has been wholly abandoned by the Navy, and we therefore undertook to repair the breach in the moat-wall in the hope that *Cassiopea* and other forms may reappear in the moat by 1922.

The total abandonment of Fort Jefferson by the Navy, with the abolition of the trips which the naval tug used to make between Key West and Tortugas, puts us to the expense of making every trip for supplies to Key West in our own vessels, the distance being 68 miles. The Tortugas have thus become the most isolated islands off the coast of the United States.

After the hurricane of 1910, many echini, such as *Toxopneustes* and *Hipponoë,* developed upon the reef-flats of the Tortugas, but the hurricane of 1919 seems to have been destructive in this respect, for these forms, so important for work in experimental embryology, are at present very rare at Tortugas. In fact, it is the opinion of naturalists who have collected in the Florida-West Indian region that within recent years the shallow-water animals have progressively become more and more rare; nor can this be attributed altogether to partial extermination by man, for many forms untouched by the fishermen are thus affected.

It is of course well known that in Oligocene times many species of corals were found in both the Atlantic and Pacific and have since become extinct in the Atlantic. We do not venture to assert that some such dying out of species may still be progressing in the tropical Atlantic, but some general cause seems to be producing a decline in the shoal-water fauna over the whole West Indian, Bahaman, and Florida region. Possibly the decided reduction in the numbers of fishes, etc., of commercial use may have had an indirect effect in causing the reduction of other forms.

When the Director first visited the Tortugas in 1897, on practically every night during the breeding-season from May until August at least one female Loggerhead turtle crawled up upon the sands to lay its eggs; but in 1921 not a single turtle crawled upon Loggerhead Key. Fishermen living in 1897 told me that in about 1860 as many as 40 turtles would sometimes crawl and be turned over upon this island in a single night, and that after turning them it was the custom to let them all die in the hot sun. In common with all other valuable commercial resources of Florida, the extermination of the sea-turtles has been phenomenal and quite in keeping with the ruin of the sponge fisheries, once the chief source of revenue for Key West, as well as the extermination of the most beautiful forms of bird life, such as the flamingo, roseate spoonbill, and crested egret.

The destruction of the littoral element of marine life will probably be hastened appreciably by the coming of the oil-burning steamer. Only three years ago the harbor water of Key West was remarkably pure, due to the absence of city sewage; and the piling of the docks was a source of an abundant marine life. Now everything between tides is thickly covered with a mass of black crude oil and the marine life between tides has disappeared. Even the remote beaches of the Tortugas are beginning to be flecked with this oil.

These conditions indicate that marine laboratories for research should be regarded as temporary establishments. Indeed, it has been the history of every laboratory that the progressive contamination of water in its neighborhood has been a source of constantly increasing embarrassment. Such contamination forced the abandonment of Professor A. Agassiz's once prosperous laboratory at Newport. The Naples laboratory was obliged to construct a branch station at Ischia in order to give opportunity for physiological work such as could no longer be performed in the sewage-laden water in the neighborhood of Naples. The great English laboratory at Plymouth and our own laboratory at Woods Hole are now forced to go far afield for many forms once abundant in the immediate neighborhood. In other words, the Department of Marine Biology should be looked upon as an agency for the study of problems of the oceans rather than as a fixed station at Tortugas, Florida. In fact, studies commenced at Tortugas have frequently led us to the Pacific for their logical continuance.

The following investigators studied under the auspices of the Department during the year:

Dr. Paul Bartsch, May 15 to June 20, Andros Island, Bahamas, and Tortugas, Florida. Heredity of characters in hybrids between Bahama and Florida cerions.
Professor Ulric Dahlgren. Histology of luminous organs of fishes, Provincetown, Massachusetts, and Bar Harbor, Maine.
Professor John H. Gerould. Heredity of characters in Pieridæ.
Professor E. Newton Harvey. Chemistry of animal luminescence.
Professor William H. Longley, Tortugas, June 3 to Sept. 1. Coloration of reef fishes with reference to evolution and environment.
Alfred G. Mayor, Tortugas, June 1 to July 25. Reactions of ants.
Professor Asa A. Schaeffer, Tortugas, June 13 to July 25. Marine amœbæ.
Professor A. L. Treadwell, Montego Bay, Jamaica, June 21 to July 25. Eunicidæ.

Accompanied by our chief engineer Mr. John Mills, Doctor Bartsch visited Andros Island, Bahamas, taking with him the small glass-bottomed launch *Bull Pup*. He was thus enabled to make a large collection of the young snails of the *glans* type of cerion from the region of Golding Cay, which he hopes to cross with the *incanum* form of the genus from Florida. The wire cages in which he was conducting these experiments upon Tortugas having been destroyed by the hurricane of September 9, 1919, they were rebuilt by Mr. Mills this summer in such manner that it is hoped they may withstand a hurricane without material damage. Doctor Bartsch was thus enabled to restart his breeding experiments upon Loggerhead Key, Tortugas, which it will take about 10 years to complete. In addition to these studies of cerions, Dr. Bartsch made observations upon the birds of the Bahamas and Florida.

In 1915, Professor John H. Gerould accompanied our expedition to Porto Rico and made a study of the Pieridæ of this island. This research has been continued upon American forms and interesting factors in Mendelian inheritance have been brought to light.

Professor E. Newton Harvey had a large collection of *Cypridina* made for him in Japan in order to endeavor to obtain a sufficient amount of luciferase and luciferin for a more definite chemical analysis of these substances. He also studied luminous organisms at Woods Hole and at Bar Harbor during the summer, while Professor Dahlgren gathered material for a study of the histology of luminous organs in fishes.

Professor William H. Longley continued at Tortugas the study he has pursued for many years upon the selective value of habits and environment in developing the color and patterns of reef fishes. He pursues the direct method of going under water in a diving-hood and observing the fishes in their natural condition. He is provided with a submarine camera, which enables him to obtain photographic records of many occurrences having a bearing upon the problem of his research.

The exceptional calms of June 1921 gave him a remarkable opportunity to extend his observations and obtain new photographs.

Alfred G. Mayor studied the reactions of the small red ant so abundant at Tortugas. It appears that when an ant finds some food (such as a dead fly) it goes toward the nest and on the way meets others, which become much excited and in turn communicate the excitement to others. Then the original ant conducts her associates back toward the dead fly. Contrary to the observation of Bethe, these Tortugas ants do not follow the *path* of the original ant, but must be deliberately led by her back to the fly. An ant with abdomen slit or cut off appears to behave normally and goes from a fly it has found towards its fellows of the nest, but these are not excited by it and do not follow it back to the fly. The "finder" ant apparently has not only a fair sense of the general direction back to the fly, but of the *distance* as well, and having gone the right distance the swarm suddenly breaks up and reconnoiters in all directions, some of them finding the fly, while many go astray.

Professor Asa A. Schaeffer continued his study of marine amœbæ at Tortugas, very little being known of these minute forms, which are exceedingly difficult to discover. He developed a number of cultures, however, which provided him with a good supply of material, as appears in his report.

Professor A. L. Treadwell went to Montego Bay, Jamaica, in order to extend his knowledge of the distribution of the Eunicidæ for a monograph upon these worms. In this study he has now visited Tortugas, Bermuda, Porto Rico, Tobago, and Jamaica.

The following papers have been presented during the year for publication by the Carnegie Institution.

C. F. Silvester and H. W. Fowler on Samoan fishes.
A. L. Treadwell. Annelids of Puget Sound.
A. H. Phillips. Precipitation of metals in sea-water.
E. N. Harvey. Luminous fishes from Banda.
R. T. Chamberlin. Geology of the reefs of Tutuila.
A. G. Mayor. Rose Atoll, Samoa.
R. C. Wells. Carbon dioxide of Tortugas sea-water.
Joseph A. Cushman. Foraminifera of Tortugas.

The publication of papers has been delayed by various causes, but the following, representing work performed wholly or in part under the auspices of the Department of Marine Biology, were published:

Bowman, H. H. M. 1920. Histological variations in *Rhizophora mangli*. 22d Report Michigan Academy of Sciences, pp. 129–134, pls. 9–12.

Cushman, J. A. 1921. Foraminifera from the north coast of Jamaica. Proc. National Museum, vol. 59, pp. 47–82, pls. 11–19.

Vaughan, T. W. 1919. Corals and the formation of coral reefs. Smithsonian Report for 1917, pp. 189–276, 37 pls.

REPORTS OF INVESTIGATORS.

Luminosity in Marine Animals, by Ulric Dahlgren.

The writer has been engaged in researches into the lighting powers of animals. One paper is nearly ready on the luminous powers of *Cypridina hilgendorfi* and a number of allied ostracods, mostly marine. The luminous organs are shown to consist of an enlargement and specialization of the dermal glands so characteristic of the group, and especially those on the upper lip, which in many forms have had the more primitive function of salivary glands. In *Cypridina* an interesting fact, hitherto unnoticed, is that one lobe of the gland on each side extends far past the middle of the animal's body, thus invalidating certain physiological work in which the cutting of the animal's body in two halves was supposed to divide it into a luciferin-bearing and a non-luciferin-bearing portion. In another light-bearing *Pyrocypris*, from the East Indies, a more primitive but efficient organ has been described.

Further work on fishes confirms Harvey's discovery that in some fishes luminous bacteria in the light organ are the principal source of the light. Measures to secure a number of deep-sea luminous fishes have been undertaken, but the time is not yet ripe for results.

Further Studies on Bioluminescence, by E. Newton Harvey.

During the autumn and winter of 1920 the author continued his studies on light production in the animal kingdom with two objects in view: first a search for new sources of luciferin, the material oxidized by luminous animals in the presence of a catalyst, luciferase; second, a study of the specificity of luciferin and luciferase. A trip was made to the Banda Islands of the Dutch East Indian Archipelago, where two fishes with very large luminous organs are found. Studies were also made at the Puget Sound Biological Laboratory at Friday Harbor, Washington; on the Dutch fisheries steamer *Brak*, off Batavia, Java; and at the Musée Océanographique, Monaco. It gives me pleasure to acknowledge the kindness of Professor T. C. Frye, director of the Puget Sound laboratory, Dr. A. L. J. Sunier, director of the Batavia Fisheries Station, and Dr. J. Richard, director of the Musée Océanographique, Monaco, during my stay at these places.

Many luminous forms new to the author were obtained, including *Polynoë*, *Tomopteris*, *Odontosyllis*, various medusæ and ctenophores, *Pyrocypris*, *Geophilus*, *Pyrosoma*, and two fishes. Some of these forms were rare, but others occurred in sufficient numbers to determine whether the luciferin of one species would luminesce with the luciferase of another, and vice versa. This study on specificity is still being continued and a preliminary paper will appear shortly. It will suffice to say now that the luciferin-luciferase reaction appears to be specific to a high degree. Only if the luciferin and luciferase come from closely related forms will they luminesce when mixed. *Odontosyllis* promises well as a source of material and *Tomopteris* will give the answer to some interesting problems in connection with the color of the light, if it can be obtained in sufficient quantity.

The marine fishes *Anomalops* and *Photoblepharon* of the Banda Islands were obtained in large numbers and physiological studies were made. Although not suited for the preparation of large quantities of luminous material, the organ of these forms turns out to be of extraordinary interest for a quite unlooked-for reason. Despite the general appearance of an organ of external secretion, no luminous material is excreted to the sea-water by the living fish. If the organ is tested in sea-water and examined under the microscope, innumerable motile, rod-shaped bacteria, sometimes forming spirilla-like chains, can be seen. Smears of the organ which I obtained in Banda have been very kindly stained for me by Professor Dahlgren, of Princeton University, and show the bacteria nicely.

In chemical respects an emulsion of the organ behaves just as an emulsion of luminous bacteria and differs in one or another way from extracts of other luminous animals. These various characteristics may be summarized as follows:

1. The light organ is extraordinarily supplied with blood-vessels, and the emulsion is fully as sensitive to lack of oxygen as are luminous bacteria. Light ceases very quickly in the absence of oxygen.
2. If dried, the organ will give only a faint light when again moistened with water. This is characteristic of luminous bacteria. The luminous organs of most other forms can be dried without much loss of photogenic power.
3. Luciferin and luciferase can not be demonstrated. This is also true of luminous bacteria.
4. The light is extinguished without a preliminary flash by fresh water and other cytolytic (bacteriolytic) agents, characteristic also of luminous bacteria.
5. Sodium fluoride of 1 to 0.5 per cent concentration extinguishes readily the light of an emulsion of the gland.
6. Potassium cyanide has an inhibitive effect on light production in about the same concentration as with luminous bacteria.

To these observations must be added the very suggestive fact that the light of *Photoblepharon* and *Anomalops* continues night and day without ceasing and quite independently of stimulation. This is characteristic of luminous bacteria and fungi alone among organisms, and very strongly suggests that the light is actually due to symbiotic luminous bacteria. The organ thus appears to be an incubator for the growth and nourishment of these forms.

Actual proof that the bacteria found in the organ are luminous can only come when these are grown artificially. My attempts in this direction have failed. Good growths of bacteria were obtained on pepton agar, but they produced no light. One might expect that a symbiotic form would require rather definite food materials to produce light, and it is perhaps not surprising that culture experiments have failed. Certainly, the ocular and chemical evidence, if not the cultural evidence, supports the view that the light of these living fish is bacterial in origin. A complete account of the fish will appear shortly in the Carnegie Institution publications.

An account of luminescence among cœlenterates, so abundant in Puget Sound, will appear in the Biological Bulletin. Work on specificity and chemical character of luciferin is being continued.

Report on the Polychæte Annelids of Montego Bay, Jamaica, by A. L. Treadwell.

From June 28 to July 21 was spent in Montego Bay, Jamaica, completing data on the species of the West Indian Leodicidæ for a publication on this family now in press; little attention was paid to members of other polychæte families. Montego Bay proved to be rather poor in annelids, as there are few mud flats and the dead, porous coral rock which affords such favorable hiding-places for these animals is largely absent from the splendid coral reefs of this bay. The area covered was from White House, about a mile east of the harbor entrance, along the shore of the bay as far as Unity Hall, on the southern shore; the coral reefs of the harbor, so far as these could be reached from a boat; and in the mud about the mangrove patches of the Bogue Islands, so far as these were practicable. In most cases the margin of the mangrove extends into water too deep for collecting, the best exception being the mud flat outside the outermost Bogue, which is, however, rather poor in annelids.

Leodice fucata, the "Atlantic palolo," occurs in Montego Bay, and I was especially anxious to secure data concerning its swarming. It will be remembered that in the Dry Tortugas this swarms within three days of the last quarter of the June-July moon, this date occurring this year on June 28. My first collecting was done on June 29, and in the coral incrusting the beach rock directly in front of the residence of Mr. Henry Doubleday I found both sexes of *L. fucata* apparently ready for swarming, as the bodies were much distended with sex products. I visited this locality early on the mornings of June 30 and July 1, but saw no swarming. This negative evidence is of little importance, as the area under observation was extremely small and the few annelids in it might have swarmed and been carried away by currents before daylight. Specimens collected at this time had lost their posterior ends and one individual collected at Unity Hall on July 14 had regenerated a posterior end about an inch long. On July 6 Mr. Edward Wallace, who has been employed as a collector for several scientific expeditions to Montego Bay, stated that he had seen worms swimming at the surface, but that it occurs very rarely; he had not seen it this year, but others had told him that it came "last week;" that it is seen along the shore (indicating the locality above mentioned where I had collected the palolo); that the worms swim very early in the morning, and that as "the sun gets hot they all fade away." This seemed to me evidence sufficient to justify the assumption that probably the palolo swarmed in Montego Bay some time in the week ending July 2.

Leodice fucata, *L. caribœa*, *L. mutilata*, and *Nicidion kinbergii* are common in the incrusting coral lying on the hard beach rock along the shore. *Leodice culebra* and *Lysidice sulcata* occur in the same localities, but are rarer. *Leodice unifrons* was very widely distributed, living in tubes on the bottoms of stones or in sandy mud in all parts of the bay. *Drilonereis attenuata* occurs rarely and a few specimens of *Lumbrinereis cingulata* were found. The only other lumbrinereid was *Arabella setosa*, collected at Reading Landing. *Marphysa regalis* was found near White House, and *M. nobilis* was collected in the mud near the outer Bogue. It is evidently rare, as three days digging failed to bring up more than the one incomplete individual found on the first day. In sponges near Sandy Point I collected a new species of *Leodice*, to be described under the name of *L. spongicola*. It is evidently allied to *L. denticulata* Webster (=*Eunice conglomerans* Ehlers), but is much smaller and of an entirely different color.

Report of the Cerion-Breeding Experiments, by Paul Bartsch.

The reported loss of the Tortugas colonies of the Bahama cerions, which were said to have been wiped out by the hurricane, made it necessary to revisit the Bahamas to secure additional breeding material for our heredity experiments. The desired adolescent specimens of *Cerion viaregis* were obtained along King's Road, Bastian Point, South Bight, Andros, with considerable difficulty, because the local population has shifted its agricultural efforts to the ground occupied by the *Cerion* colonies in our 1912 visit. The colony of *Cerion viaregis*, in its native habitat, is therefore less flourishing to-day than it was nine years ago.

The same state of affairs, only in a still more exaggerated form, obtains in the *Cerion casablancæ* colony, for sheep and pigs have been introduced in the region occupied by this species. The larger vegetation has been cut down with the ax in order to improve the habitat for grass culture, and the smaller vegetation, grasses and shrubs, are being rapidly eliminated by the grazing sheep, while the mollusks themselves are sought by the pigs. If this state of affairs continues this colony will probably disappear altogether, extensive as it was in 1912. The necessary specimens for our experiments, however, were secured by a diligent and exhaustive search. In addition to the breeding material, we also secured a set of adults of both *Cerion viaregis* and *Cerion casablancæ* for comparison with the material gathered in 1912.

During our trip to the Bahamas, gatherings of cerions were made from every colony discovered along the east-central shore of Andros and the banks of South and Middle Bights. While waiting for transportation to Miami from Nassau, we put in use the *Bull Pup*, a small motor-launch that we carried to the Bahamas with us, and thoroughly explored all the cays lying off southwestern New Providence for cerions, and we believe that we charted every colony on those islands and the adjacent shores of the mainland. These gatherings, embracing more than 20,000 specimens, may serve as a check series with which future gatherings from the same colonies may be compared.

We returned to Miami June 3; on the 4th we sailed south for the Tortugas, our first stop being on the First Ragged Key north of Sands Key, which by filling in with dredges has been rendered many times its former size, and the region occupied by our cerion colony has been completely covered with dredged-up ocean bottom, so that this colony, we may say, is completely buried.

The Second Ragged Key north of Sands Key appears to have been pretty well swept over by the high water occasioned by the hurricane, and only a few specimens of our cerion colony were observed. However, an exhaustive search was not made, as we wished merely to establish at this time the approximate state of the colony. The mosquitoes, too, this year were about the worst that we have encountered on the east coast.

The planting on the east side of Sands Key was again visited, but no specimens were observed in the rank vegetation which covers the place.

The Indian Key colony seems to have been saved by the rank growth of sisal and other vegetation, but no specimens were seen on Tea Table Key.

I was unable to find any cerions on Duck Key.

On Bahia Honda Key the hurricane has made decided changes. The ditch along which our planting was made now separates the outer portion of the key almost into a distinct island. A lake of considerable size occupies the place where our planting was located and none of the introduced cerions was seen.

The hybrid colony on Newfound Harbor Key, in which our greatest interest centered, strangely enough seems to have suffered less than any other. Notwithstanding the location of this colony was rather low, it was not destroyed, as was feared. Evidently the rain preceding the hurricane had caused the cerions to take to the ground, as they usually do for foraging purposes under such conditions, and the dense mats of grass here had kept them from being swept away by the floods that must have passed over them; yet many dead specimens were found, which were taken for record purposes.

At Key West a gathering of adolescent *Cerion incanum* was made near the aquarium site for our breeding experiments.

The colony at Boca Grande has suffered much through fire and storm, yet specimens could be easily seen.

At the Tortugas, the colonies on Loggerhead Key were in better condition than I have seen them on any previous visit. In fact, I believe more of *Cerion viaregis* and *Cerion casablancæ* exist on Loggerhead Key to-day than in their native habitat. The only effect that the hurricane has apparently had upon our colonies at the Tortugas is that the water carried some of the specimens a considerable distance from the place where they were planted, so that it is quite possible that in the future there may be considerable intermingling of the animals in various parts of the islands.

The colony of *Cerion uva* is just beginning to show adult specimens. This shows a much longer developmental period than is the case in the Bahaman species. Of the latter, as stated before, we were able to obtain mature generations in three years, while the *Cerion uva* colony was planted in May 1916, which indicates five years as a developmental period.

In the report "Experiments in the breeding of cerions," Department of Marine Biology, Carnegie Institution, vol. XIV, 1920, we gave on page 46 detailed measurements of 100 specimens representing the check series of *Cerion crassilabris* from Balena Point, near Guanica Bay, Porto Rico, which were planted on Loggerhead Key in 1915. These were figured on plates 48 to 50. On page 47 we gave measurements, and on plate 51 figures of 36 adult shells of the first Florida-grown generation gathered in January 1919. This year we found a much larger series of first-generation material, and the following table gives a summary of measurements of 200 of such specimens:

Comparison of measurements of Florida-grown Cerion crassilabris with the check series.

	No. of whorls.		Altitude.		Greatest diameter.	
	Check series.	First generation.	Check series.	First generation.	Check series.	First generation.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Average	9.55	9.13	22.13	22.36	12.41	11.89
Greatest diameter	10.5	10.4	27.5	25.7	13.9	12.2
Least diameter	8.5	8.6	19.0	19.6	10.6	10.4

It is interesting, therefore, to note that the first generation of this Porto Rican cerion is in complete agreement with the facts adduced from the two Bahaman species.

The hurricane of 1919 destroyed the cages in which we had placed a specimen of each of two species, in order to determine their ability to hybridize and to note the results of such crosses as might be observed from such selected individuals. A new set of cages was therefore prepared. Eleven groups of these cages consist of four compartments each, a cubic yard in size. The septa between compartments are double wire walls to prevent possible mating through the meshes of the fine Monel metal-wire screen. In each of these cages we placed a *Hymenocallis* plant, some grass and dead-wood rubbish, in other words, habitat conditions which we found favored by cerions at the Tortugas. Then two half-grown specimens, one of *Cerion viaregis* and one of *Cerion incanum* from Key West, were placed in each of the 44 compartments. These cages are securely anchored, and every precaution has been taken to make sure that the mollusks will be confined within them, and that no extraneous individuals can find entrance.

Cages No. 45 and No. 46 are of the same size as those last mentioned. In cage 45 we placed 183 young of *Cerion incanum* from Key West, in order to determine what percentage of these will reach maturity. In cage 46 we placed an abnormal specimen of *Cerion viaregis.* This had a spiral keel, which may be the result of an injury, although I was unable to discover any sign of it. With it I also placed a normal specimen of *Cerion viaregis* in order to determine if this character might be transmitted to offspring.

In addition to these, five groups of cages were made which have the same size as the four unit cages, but they have only one partition in the middle, thus making them 3 by 6 feet and 3 feet high. In these we placed the following combinations:

No. 47. 25 each of *Cerion incanum* and *Cerion viaregis.*
No. 48. 25 each of *Cerion incanum* and *Cerion casablancæ.*
No. 49. 25 each of *Cerion incanum* and *Cerion uva.*
No. 50. 25 each of *Cerion incanum* and *Cerion crassilabris.*
No. 51. 25 each of *Cerion viaregis* and *Cerion uva.*
No. 52. 25 each of *Cerion viaregis* and *Cerion crassilabris.*
No. 53. 25 each of *Cerion casablancæ* and *Cerion uva.*
No. 54. 25 each of *Cerion casablancæ* and *Cerion crassilabris*
No. 55. 25 each of *Cerion uva* and *Cerion crassilabris.*

In cage 56 I placed 203 young of various sizes of the huge new form collected in Middle Bight, Andros, which I have called *Cerion mayori.*

Two additional species were introduced this year on Loggerhead Key, one *Cerion mayori,* as above stated, and the second, *Cerion incanum,* as also stated above, but of this species we also placed a large colony about the water tower at the northern end of the island, in order to have additional material if we should need it for breeding purposes in the future.

Investigation on Marine Amœbas at Tortugas, Florida, by Asa A. Schaeffer.

The work on amœbas during June and July 1921, at Tortugas, Florida, was a continuation of work begun there in 1919. The greater part of the time was devoted to a systematic study of marine amœbas. All the species discovered in this locality in 1919 were found again this year, and 16 new species were discovered and described. Several more species were found whose descriptions, for one reason or another, remain incomplete. More species have been reported from this station than from all other marine stations together. The observations on the systematics and distribution of marine amœbas have advanced far enough to warrant the following tentative conclusions:

(1) The sea is probably richer in species of amœbas than fresh water. The number of species in existence is very much larger than is commonly thought. Judging by the number reported from time to time in both fresh and salt water, amœbas seem to be as numerous in species as, for example, the Foraminifera.

(2) Marine amœbas are distinct from fresh-water species. No species has yet been found living and reproducing in both fresh and salt water.

(3) The average size of fresh-water amœbas is larger than that of marine amœbas.

(4) The most important factor affecting the distribution of amœbas is the food-supply. A few species live on bacteria, but the majority live on diatoms and other algæ. It follows, therefore, that the largest number of species and individuals are found where diatoms abound.

(5) Other important conditions affect distribution, for some species occur in great numbers in natural and artificial cultures, while comparatively few

individuals of other species are found in cultures at the time of their maximum concentration.

The method of treating amœbas with varying dilutions and concentrations of sea-water for the purpose of detecting specific differences, which was discovered in 1919, has been applied to all the new species discovered this season, with even better results than had been hoped for. Some species very similar in general appearance are found to react in a strikingly different manner to diluted sea-water. This test has proved to be one of the most important for the quick and accurate determination of species.

After the season at the Tortugas Laboratory was over, a few weeks were devoted to examining amœbas found at Cold Spring Harbor, New York, to obtain evidence on geographical distribution. Of the 20 species reported from Tortugas, 5 were found at Cold Spring Harbor; 5 new amœbas were also found, 2 of them being very common, while the other 3 were relatively rare. Several other new species were observed, but they could not be described adequately for want of time. The indications are, therefore, that amœbas are subject in their geographical distribution to general principles, similar to those that govern the distribution of many other groups of animals.

Studies on the Pieridæ, New Mutations in Colias philodice, by John H. Gerould.

In August 1920 about 45 conspicuous blue-green caterpillars developed in three cultures of the common sulphur butterfly, *Colias philodice*, that had been inbred for two generations in the study of the inheritance dimorphism (white wing-color) in the female.

The normal grass-green color of the caterpillars of this species is due to the pigments in the hemolymph derived directly from chlorophyl of the food-plant (clover). The hemolymph of the mutant caterpillars, however, as well as the hypodermis, is blue-green. The pupa is likewise bluish, instead of yellowish grass-green. The eye-color of the adult also is bluish green, not yellow-green; the hemolymph color of the butterfly is identical with that of the mutant caterpillar, blue-green. The pigments of the hemolymph correspond in both the mutant and normal butterfly to the (hypodermal) color of the compound eye.

The egg laid by a female with blue-green hemolymph is of a brilliant pure white, not the normal cream-white. The cocoon color of braconid larvæ that have parasitized the blue-green caterpillar, fed upon the blue-green blood, and emerged to spin upon the surface of the dying caterpillar, is pure white, lacking the bright yellow color of the normal cocoon.

Blue-green hemolymph thus lacks a yellow pigment, probably derived normally from xanthophyl. This is not the yellow pigment of the wing-color, which is known to be a derivative of uric acid deposited in the scales upon the wing, for the wing-color of butterflies having the blue-green hemolymph is of the normal yellow color, unaffected by this mutation.

Blue-green hemolymph is a simple non-sex-linked Mendelian recessive. Originally produced by two generations of inbreeding from a female presumably heterozygous for it, blue-green individuals thus far have proved nearly sterile. When fertile, they breed true. They are vigorous as caterpillars and adults, but they lack almost completely the instinct for mating.

The blue-green caterpillars that hibernated in 1920–21 produced butterflies that failed to mate, but fortunately several females of the same stock survived from a pair of grass-green parents of which the male was known to be heterozygous for blue-green. To save the race, these surviving females, of which presumably one-half were heterozygous for the blue-green, were mated early in the season (before adult butterflies of this species had appeared in New Hampshire) with wild males from a more southern locality (Annandale-on-Hudson, New York).

The four families of grass-green larvæ produced by back-crossing with wild stock came to maturity in June. By good fortune, the largest of these families contained heterozygotes for blue-green, for, when inbred in July-August, 3 out of the 9 matings gave 25 per cent of blue-green larvæ. In addition to the blue-green, a new recessive mutant, *olive-green*, occurred in two of these three families, one giving a clear-cut 2 : 1 : 1 ratio, viz, 95 grass-green: 46 olive: 44 blue-green; another 9 : 3 : 4, i. e., 40 grass-green: 17 olive: 29 blue-green. The third mating producing blue-green gave simply 31 grass-green, 10 blue-green, with 1 olive, probably a waif from another culture.

Olive-green mutant caterpillars also appeared, in company with normal grass-green and in the simple 1 : 3 ratio, in 4 more of these 9 inbred families. The total numbers in these 4 families were 128 olive, 314 grass-green.

Olive-green caterpillars have grass-green hemolymph, in which I am unable to detect any color difference from the normal. The color is hypodermal rather than cuticular, and is probably due to a physico-chemical change in the hemolymph, for the scale-pigments of the under side of the hind wing and of the tip of the fore wing, parts most exposed to the action of the hemolymph in the pupal wing-bud, take on an *orange*-yellow hue ("lemon chrome," 21, O-YY Ridgway, in the male; "empire yellow," in the yellow female; buff, or "mustard yellow," in the white female).

Moreover, the eye of the adult butterfly from an olive-green caterpillar is also olive-green, a color corresponding to that of the caterpillar, but a shade lighter.

The general conclusions are as follows:

(1) The (hypodermal) eye-color of the normal adult *Colias philodice* and of each of these two mutants corresponds in each case to the (hypodermal) color of its caterpillar. In both the normal and in the blue-green this color is identical with that of the underlying hemolymph.

(2) The hemolymph supplies both the compound eye and the larval hypodermis with the normal grass-green, or with the blue-green, pigment.

(3) The pigments of the hemolymph are derived from chlorophyl of the food-plant, and a yellow element, probably derived from xanthophyl, is suppressed in the hemolymph of the blue-green caterpillar (i. e., blue-green-blooded butterfly).

(4) Absence of yellow pigment in the blue-green hemolymph changes the silk spun by the parasitic larva living in it from yellow to pure white, and similarly yellow-free blue-green hemolymph produces a blue-green hypodermis both in the skin of the larva and in the compound eye, though it is probable that —

(5) the primary reaction of the hereditary factor for blue-green acts from the nuclei of the intestinal epithelium directly upon dissolving chlorophyl during digestion, destroying xanthophyl.

(6) That the hemolymph of the olive caterpillar, though apparently normal in color, directly determines the hypodermal color of the caterpillar and compound eye is substantiated by the orange effect produced upon the wing-scales on those portions of the under surfaces of the developing wings that are most exposed during development to the physico-chemical action of the hemolymph.

(7) The immediate physical basis of these and other hereditary characters in *Colias* is not chromosomes but substances dissolved in the hemolymph. Upon this substratum, genes, probably chromosomes or parts of chromo-

somes, act as catalysts to inhibit, modify, and in rarer cases to promote development. The nature of genes should be sought in physico-chemical investigations of blood and lymph in pedigree cultures; for, if chromosomes are the vehicle of genes, blood and lymph are the media through which they act in the control of development. In such studies the spectroscope is likely to be found most useful.

Preliminary experiments are being made in breeding *Colias interior* Scudder, a subarctic species found in northern and north-central Canada and also in the White Mountains only 50 miles north of the site of Dartmouth College (Hanover, New Hampshire).

Habits and Local Distribution of Tortugas Fishes, by W. H. Longley.

Study of the habits and local distribution of fishes occurring at Tortugas was continued with satisfactory results from June 7 till August 25, 1921. During this time photographs were secured recording the appearance, alternative color-phases, or interesting activities of 25 species.

In the course of more intensive effort than had been made hitherto to determine with accuracy the distribution of local species in the shallow waters of the atoll, nearly 30 were discovered with which the writer had no previous acquaintance. Of these, 4 or 5 are perhaps new to science. The finding of others at Tortugas greatly extends their range. Such is the case, for example, with *Prionodes baldwini* (Evermann and Marsh), otherwise known only from Porto Rico. *Ioglossus calliurus* (Bean), known hitherto only from the Pensacola snapper-banks, where it has been found in the stomachs of other fishes, belongs in the same class. It is rather common at Tortugas on a certain sort of bottom covered with small fragments of dead coral. It is small, alert, inconspicuous in coloration, and never appears to go far from its burrow. It is, therefore, well adapted to escape observation and capture by ordinary methods. The adults commonly occur in pairs sharing the same burrow, as do also sometimes as many as 7 or 8 small ones. The young have a symmetrical bilobed caudal quite unlike the lance-shaped fin of the adult.

There is uncertainty at present regarding the relation to one another of the different species of *Eupomacentrus* to be found in the West Indian region and adjacent waters. The difficulty in classification appears to be due largely to the fact that their coloration changes greatly with age, and also that they possess (in common with perhaps the greater number of tropical reef-fishes) powers of instantaneous reversible color-change.

At Tortugas 4 species occur, or 5 if *E. leucostictus* (Muller and Troschel) and *E. analis* (Poey) be not one, as observation indicates they are. The others are *E. fuscus* (Cuvier and Valenciennes), *E. planifrons* (C. and V.), and a black and white or dark brown and pale yellow species, which is apparently *E. partitus* (Poey). The very young *E. partitus* has not been taken at Tortugas; but while very small specimens of *E. fuscus* are rather rare during the summer months, *E. planifrons* a centimeter or two in length is not uncommon, and *E. leucostictus* of the same size is abundant. The young *E. fuscus* is brick-red antero-dorsally, otherwise dusky, except for a large ocellus on the soft dorsal fin and another upon the dorsal surface of the caudal peduncle. The young *E. planifrons* is yellow, with an ocellus on the soft dorsal, corresponding to that of *E. fuscus*, and a conspicuous black spot on the dorsal side of caudal peduncle. *E. leucostictus* is purple antero-dorsally, otherwise yellow. It has a dorsal ocellus, and may or may not develop a spot upon the caudal peduncle.

A goby of the genus *Gobiosoma* almost invariably shares the burrow of a species of shrimp which the latter makes in fine sand or mud. The fishes are very abundant in large, deep holes in the reef flats. Two fishes and two shrimps have been seen living together, but usually only one of each appears to share the burrow.

Species of *Gnathypops* and *Opisthognathus* dig and occupy holes in a sandy or stony bottom, and are able to line vertical shafts and prevent their collapse. They have been seen working in the bottom of funnel-shaped depressions, whether excavated by themselves or not is uncertain. About the mouth of a shallow pit in the bottom of such a hole they arrange a circle of stone or bits of shell not too large to be carried in their mouths, and support these externally by banked sand brought up from the burrow or carried in from outside. From time to time additional stones are laid in place, additional sand is brought, and their building is carried up until it reaches the level of the surrounding bottom, or even rises above it. The plumbness and fit of the shaft are assured by the fact that when the fish returns with a coral fragment in its mouth it goes down into its hole tail first and lays its burden accurately in position, or moves it repeatedly until it is fitly adjusted. *Opisthognathus macrognathum* (Poey) may build in this way a retreat a foot or more in depth, with a shaft an inch or more in diameter, and with a terminal chamber of a pint capacity. The fish usually stands in its burrow with its head scarcely rising above the general surface, and when it retires it may draw in and block the opening with a piece of coral relatively huge in proportion to its own size and weight.

Thalassoma nitidum (Gunther), which the writer has perhaps incorrectly considered the young of *T. bifasciatus* (Bloch), is apparently an active gleaner of ectoparasites from the bodies of other fishes. It may commonly be seen pecking at their sides and fins. Carangids, tangs, and others come singly or in groups again and again to the point where the *Thalassoma* is temporarily located, one might almost say with the specific intention of submitting themselves to its inspection. A chub, *K. sectatrix* (Linnæus), has been observed to drive away others repeatedly to a distance of 20 feet or more and to return promptly and permit the interrupted grooming to be resumed.

It is interesting to discover a blenny, apparently an undescribed species very like *T. nitidum* in color, very rare, found sometimes in its company. The relation between the two species seems comparable to that between Batesian mimics and their models in the case of Lepidoptera. It will be interesting to learn whether *T. nitidum*, on account of its beneficent ministrations, or for other reasons, enjoys immunity from attack which the unnamed species might share on account of its similarity in appearance.

Epinephelus morio (C. and V.), *E. striatus* (Bloch) *Kyphosus secttarix* (Linnæus), and several species of *Eupomacentrus* show more or less distinctive color-phases when in pursuit of other individuals of their respective species which may have entered their private preserves, or otherwise provoked attack. These changes in color are examples of those to which Mr. Charles H. Townsend has called attention as a result of his observations on fishes in the New York aquarium. In some degree at least they appear to differ in cause and significance from other color-changes occurring in these and other species. For it remains true in general that the evidence indicates that the chief function of fixed or changeable coloration in tropical reef fishes is to render them inconspicuous under the conditions in which they live.

DEPARTMENT OF MERIDIAN ASTROMETRY.[1]

BENJAMIN BOSS, DIRECTOR.

As in previous years, the work of the Department has been mainly divided between computation in preparation of the observations taken at San Luis and at Albany for catalogue form, preparations for the derivation of proper-motions and star places for the general catalogue, and a number of researches in various astronomical fields.

The operations necessary to the completion of the observations and of the general catalogue, while numerous and requiring long-continued effort, are of little general interest in the main. Consequently, only those steps which have more than a general interest are reported, though they form but a small fraction of the total output of effort.

ABSOLUTE MAGNITUDE.

In addition to the conclusions drawn in the last report of the Department regarding absolute magnitudes, some other deductions of interest have been made. For the material used there is a steady progression in the size of the proper-motion with progression in the size of the absolute magnitude, indicating increasing velocity of the stars with decrease in absolute magnitude, though the effect is enhanced because the increase in the proper-motions is partly due to decrease in distance. The same general effect of increase in velocity with decrease in brightness is also shown through the treatment of the radial velocities. There is a sharp increase in the velocity between 3.5 and 4.5 absolute magnitudes. The distribution of the absolute magnitudes is fairly well represented by a probable-error curve, with a maximum at +3.3 absolute magnitude and a probable error of ±2.0. Two velocity curves, one for giant stars and the other for dwarfs, would probably fit the observed data more closely. There are some marked deviations from the curve, especially that occurring between +0.8 and +1.2 absolute magnitudes. A division of the absolute magnitudes of the giant stars according to galactic latitude showed no appreciable change.

SPACE MOTIONS.

A further investigation of space motions has been undertaken, employing the corrections for parallax which were previously determined. The radial velocities used were those determined at the Lick and Mount Wilson Observatories, and the proper-motions were taken from the Preliminary General Catalogue. Only those stars were used where the material was sufficiently trustworthy, and even then comparatively small changes in the observed data would in many cases change considerably the location of the apices of motion of some of the stars employed; but for general statistical considerations the data furnish a very fair representation of the distribution of the motions of these stars. Dividing the material according to velocity into two groups of stars, the first consisting of 446 stars whose velocity does not exceed 80 km. per second, and the second including 71 stars of velocity ranging from 80 to 500 km., the apex of solar motion was found to be at right-ascension 270°, declination +28° from a solution of the first group, with a velocity of 21 km. per second for the sun.

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[1] Address: Dudley Observatory, Albany, N. Y.

The apex of solar motion derived from the high-velocity group placed the apex at 298° right-ascension and +47° declination, with a solar velocity of 89 km. The high velocity for solar motion as derived from this latter group, and the location of the apex, is ascribed partly to the peculiar distribution of the velocities of the rapidly moving stars. The peculiarity in the motion of these stars was noted in the report of the Department in the Year Book for 1918. The stars are found to be moving approximately in a region of the Galaxy extending from galactic longitude 130° to 340°. The fact that no stars of high velocity are moving toward points opposite this region renders it probable that we are dealing with a physical group and certainly accounts for the high velocity of the solar motion derived from such data.

It is also very probable that the increase in the declination of the apex of solar motion with decrease in apparent magnitude, found when the stars have been divided according to apparent magnitude, is attributable to the same cause, for in general the stars of fainter magnitude employed in the investigations are those with high-space velocities. The group of high-velocity stars is not similar to such groups as the Taurus cluster, for it fans out, but the motions of these stars are entirely at variance with general motions and demand further investigation to determine the cause of the phenomenon.

As a matter of interest, partly to test the effect of a change in the value of the parallax upon the computed elements, a space velocity of 100 km. per second was assumed for 63 members of the group and the parallax of each star was computed on this basis. It was generally found that the computed parallax differed by a small amount from the observed parallax. This suggests the bare possibility that the space velocities of at least many of these stars may be similar in size. A division of the material into giant and dwarf classifications placed the solar apex at 269° right-ascension, +18° declination for the giant stars, with a solar velocity of 20 kilometers, and at right-ascension 275°, declination +36° for the dwarf stars, with a solar velocity of 25 kilometers per second. It seems probable from the material treated that the sun's velocity in space is somewhat greater, therefore, than the generally accepted value. The A and B type stars were not used in the division into giant and dwarf classifications because of the difficulty in assigning a star of these types to either group. A separate solution of the 72 stars of these types placed the solar apex at right-ascension 262°, declination +35°, and furnished a value of 14 km. for the solar velocity.

The determination of the principal axes of the velocity figure for the different divisions is given in the table.

	A^1.	D^1.	A_2.	D_2.	A_3.	D_3.
Giant.........	101°	+ 5°	5°	+49°	196°	+41°
Dwarf.........	89	+27	273	+63	180	+ 2
A and B......	98	+14	1	+28	212	+59
$V<80$.......	92	+20	316	+12	188	+16
V 80-500.....	84	+48	291	+38	190	+14

The velocity figure for the giant stars is less flattened at the pole toward the pole of the Galaxy than that of the dwarf stars. The same difference also exists between the stars of smaller space velocity compared with the stars of large velocity. The position of the vertex of preferential motion for the large-velocity stars, taken with the peculiar distribution of the motions of these stars, accounts for the shift in the position of the sun's apex as derived from them. The velocity figure of the A and B stars proved not only exceedingly flat in the direction of the pole of the Galaxy, but the secondary axis is also small, being but half the size of the principal axis.

Grouping the stars according to type and separating the types in turn into giant and dwarf classifications, it is found that the space velocity both for giants and dwarfs increases with progression in type from B to M types. The increase of the velocity with progression in type was unexpected in the case of the giant stars and is somewhat hard to explain according to the more generally accepted theories regarding stellar evolution. When the stars were grouped according to divisions in absolute magnitude it developed that the velocity increased with decreasing intrinsic brightness of the star. The space velocity of the star seems to be a linear function of its absolute magnitude.

Five possible groups of stars were picked out, two of them the known ones of Taurus and Ursa Major. The apex of the Taurus group was placed at right-ascension 96°, declination +33°, with a group velocity of 29 km. The apex of the Ursa Major group was placed at right-ascension 282°, declination +2°, with a group velocity of 32 km. A very real-appearing group was located with an apex at right-ascension 100°, declination +22°, and a group velocity of 30 km. Two other possible groups were found, the first with an apex at right ascension 97°, declination +12°, with a group velocity of 73 km., and the second with its apex at 268° right ascension, +28° declination, and a group velocity of 17 km. Mr. Raymond and Mr. Wilson have been associated with the Director in this investigation.

DIURNAL TERM IN CLOCK-RATE.

In the last report of the Department, Year Book 1920, attention was called to a diurnal term in the right ascensions determined at Albany, Greenwich, Cape of Good Hope, and Pulkova. Mr. Varnum has continued his investigation of this phenomenon, employing various tests to determine the nature of the disturbing element causing the phenomenon. The fact that clocks of different makes, those running free, and those under barometric and temperature control, exhibit the same phenomenon seemed sufficient to discredit the idea that the irregularities lay in the clock itself. It did seem very reasonable that light passing through miles of an atmosphere which is subject to changing conditions might appreciably affect the observations. The greatest care was exerted to free the observations from all known sources of error. This was more readily effected because the observations had been planned in a manner to thoroughly discuss any peculiarities which might be outstanding in them. The residual errors of separate series of observations were then tested on the assumption that changing conditions of the atmosphere produced a varied refractional effect.

It is reasonable to suppose that the heating and cooling effects of the atmosphere due to the position of the sun might produce effects in the atmosphere which would introduce a diurnal term in the observations. In order to inspire confidence such a term should improve the observational data. It was found that the introduction of such a term in the right-ascensions greatly reduced the systematic corrections in right-ascension depending upon right-ascension and declination. A like improvement was also noted in the effect east *minus* west and in upper *minus* lower. In addition, it was noted that series of observations which appeared to be inharmonious proved to be those series where the refractional effect is most pronounced, so that apparently discordant results are harmonized. If the phenomenon is a natural one due to variation in refraction, then it should affect the zenith distances as well as the right-ascensions.

The work upon this phase of the problem has barely started, but for the few series treated it has yielded interesting results. It has apparently demonstrated that the observations taken at any particular time are subject to a systematic shift. When the refractional term is introduced, the individual star positions, with very few exceptions, are brought into greater accordance. Considerable work is yet to be undertaken upon the investigation, but it seems eminently worth while, as the results promise to correct the positions of the poles and the equator; thus, to a large extent, observations taken north and south of the equator will be harmonized. In this way it is hoped that we may be able to bring about a better standardization of star positions from pole to pole.

STELLAR WAVE-LENGTHS.

Mr. Albrecht has continued his study of stellar wave-lengths. Wave-lengths have been computed for all measures which were deemed suitable in Publications of the Lick Observatory, Vol. IX, Part II. The immediate use for these wave-lengths was twofold: (1) to test, for the measures of Dr. Palmer and Professor Wright, the variations of wave-length as a function of stellar type which had previously been published, and (2) to discuss these variations with special reference to the distinction between the giant and the dwarf stars.

For the first test the results are quite definite, the measures of Dr. Palmer and of Professor Wright for certain lines showing variations of wave-length with type which are very similar to those previously found, principally for the measures of Albrecht. The second test could be only partially completed at this time, due to the fact that for the present only an inadequate separation of the stars in this list into the giant and dwarf classes is possible. However, with the aid of Russell's rule for the individual assignment of stars to the giant and dwarf classes on the basis of stellar proper-motions, it was shown that the published curves of variation of wave-length with type pertain to the giants, being based overwhelmingly on giants. Only a moderate amount of revision will be required for these. For the determination of the curves for the dwarfs there will be required (*a*) additional stellar parallaxes for the stars in the above list, and (*b*) a detailed study of the spectra of a specially selected list of known dwarfs. At Professor Frost's suggestion the published measures on the standard velocity stars were also tried. However, it was found that the dwarf stars are not at all represented in this list. Preliminary reports on the above investigation have been made at the last two meetings of the American Astronomical Society.

SYSTEMATIC CORRECTIONS TO THE PRELIMINARY GENERAL CATALOGUE.

Mr. Roy, assisted mainly by Mr. Jenkins and Miss Buffum, has discussed the systematic corrections for most of the catalogues issued since the publication of the Preliminary General Catalogue and has determined their weights. The results, which are now in press, will furnish those who desire proper-motions in advance of their definitive determination and publication with the material from which they may derive approximate results. The systematic corrections derived from those catalogues, of a more or less fundamental nature, indicate a definite correction to the system of the Preliminary General Catalogue, as was anticipated, though the agreement among the catalogues is not wholly satisfactory.

REDUCTION OF OBSERVATIONS.

The reduction of the San Luis zenith-distance observations, under the supervision of Mr. Roy, is now practically completed. The precessions in both right-ascension and declination are computed and checked and the declinations are reduced to the mean epoch 1910.0. Means of the observations in declination are being formed and a further scrutiny of discordant results is being made. The secular variations also have been largely duplicated.

With the near completion of the San Luis zenith-distance reductions, Mr. Roy has been able to make greater progress in the reduction of the Albany zenith distances. The first discussion undertaken was of the observations made by each observer of stars, both above and below pole, to ascertain a system representing the Albany instrument and observers. The first results obtained, the latitude and the correction to the Pulkova refractions, are as follows:

A. J. Roy	+42° 39′ 12″.78	−0″.036 tan Z. D.
W. B. Varnum	+42° 39′ 12″.85	−0″.174 tan Z. D.

It is to be noted that after Mr. Varnum has obtained definitive results for the effect of irregular refraction upon the observations, it will become necessary to rediscuss the observations in order that this term may be introduced in the final results. The promised gain in the harmonizing of the observations fully justifies this step being taken.

MISCELLANEOUS INVESTIGATIONS.

Mr. Wilson continued his work on the selection of standard stars for a photographic survey until April 1921, when the project was postponed. The material gathered will be furnished to anyone desiring to use it.

Mr. Wilson also investigated the relation between period and eccentricity in binary systems. Treating 235 systems, he found an apparent rapid increase in eccentricity depending upon the period in systems with a period less than 100 days, followed by a minimum for the systems with a period of from 100 days to 50 years. When the material was divided into giant and dwarf classifications, the relatively rapid increase in eccentricity in the shorter-period binaries seemed to be largely due to the predominance of giant systems in these groups. An increase in the number of dwarf systems would tend to flatten the curve. The minimum referred to is partially due to the systematically low eccentricities of the dwarf stars in these groups and partially to the greater probability of the discovery of the less eccentric orbits among the long-period spectroscopic binaries. As more spectroscopic binaries with long periods are added it is probable that most of the discordances from a uniform mean period-eccentricity curve will be removed.

Mr. Wilson has computed the orbits of three spectroscopic binaries *l* Carinæ (interesting because of its being a Cepheid with a period of 35.5 days), β Doradus, and θ Sagittarii.

The Director, accompanied by Mr. Wilson, left in August 1920 for the southwest to test observing conditions in that region. Mount Wilson, Mount Hamilton, and the region around San Diego were visited in California; Tucson, Prescott, and Flagstaff, in Arizona; and Albuquerque and Santa Fé in New Mexico. The tests were carried on by means of star trails taken with a 5-inch photographic doublet of 13 feet focal length, the same instrument used in an exploration of the South Atlantic States.

It might be stated in general that the seeing conditions in the southwest furnish no appreciable advantage over the conditions in the favorable region of the southeast described in the last annual report of this Department. A distinct advantage, however, results for most classes of observation through the greater number of clear nights per year and, in the case of the desert regions, through the greater transparency of the atmosphere.

STAFF.

The Director has been engaged on special researches. He undertook an extensive investigation of the observing conditions in the southwestern States during the first three months of the year. Dr. Sebastian Albrecht continued his researches on standards of wavelength. Mr. Sherwood B. Grant has been engaged on a number of the processes of reduction in the formation of the catalogues. Mr. Heroy Jenkins continued his work on the derivation of systematic corrections to star catalogues. Mr. Harry Raymond has assisted the Director in the determination of the stellar space velocities and has been also engaged with many departments of the work. Mr. Arthur J. Roy was in charge of the Department during the absence of the Director. He has continued his supervision of the reduction of the zenith-distances and has also supervised the computations for the systematic corrections to star catalogues. Mr. William B. Varnum has devoted his energies toward a solution of the problem of the diurnal variation in clock-rate. Dr. Ralph E. Wilson accompanied the Director on his expedition to the southwest to observe climatic conditions. He has also assisted the Director upon special investigations and has undertaken a number of personal investigations. Miss Alice M. Fuller has continued as secretary of the Department.

As usual, the computing staff has been engaged on the various computations involved in the reduction of observations and in the investigation of various problems. It has consisted of Miss Marion F. Benjamin, Mrs. Lillian F. Blanchard, Miss Grace I. Buffum, Mrs. Livia C. Clark, Miss Mary M. Kampf, Miss Isabella Lange, Miss Marie Lange, and Miss Frances L. MacNeill, together with four miscellaneous computers employed temporarily upon the work.

MOUNT WILSON OBSERVATORY.[1]

GEORGE E. HALE, DIRECTOR.

SUMMARY OF THE YEAR'S WORK.

Three outstanding events, combined with vigorous and successful work in all departments of research, render the past year a memorable one in the history of the Observatory. The first of these is the publication by Dr. Adams and his associates of the absolute magnitudes and parallaxes of 1,646 stars, and the deduction from these results of the important generalizations outlined in this report. The second advance of great significance is the successful application of the interferometer by Messrs. Michelson and Pease to the measurement of star diameters. No less important in its future possibilities is the establishment in Pasadena of the Norman Bridge Physical Laboratory of the California Institute of Technology and the acceptance by Dr. R. A. Millikan of its directorship. It will be advantageous to consider the bearing of these events on the progress of the Observatory before summarizing the other activities of the year.

The two first-named advances, and in a different sense the third, illustrate the value in research of the development of new instruments and methods. Prior to 1900, only 60 stellar parallaxes had been measured by the laborious methods, for the most part visual, applied up to that time. The work of Dr. Schlesinger with the 40-inch Yerkes refractor initiated a school of parallax measurers, whose efficient use of photographic methods added new and more precise determinations at such a rapid rate that the total number of trigonometric parallaxes is now about 1,400. In 1915, Dr. Adams began systematic application with the 60-inch reflector of an entirely new method, which gives a parallax measure, of high precision, from the simple comparison of the relative intensities of two lines on a stellar spectrum photograph. In five years 2,000 stellar parallaxes have been determined at Mount Wilson by this beautiful process, which has been applied with the 100-inch reflector to stars as faint as the 9th magnitude, and could be pushed to much fainter objects. Thus, while the value of trigonometric parallaxes is by no means diminished, but rather increased, by the introduction of the spectroscopic method, the range of action and the rate of progress have been advanced in very high degree.

The best evidence of this advance is afforded by the conclusions based on the new measures. In complete confirmation of the earlier work of Adams and Joy, these establish beyond doubt the validity of Russell's views on giant and dwarf stars. In their early or giant stage the stars are immensely inflated gaseous masses, so tenuous that their density may be as low as one-thousandth that of atmospheric air. As they condense, their temperature rises and their reddish color changes to yellow and then to white. A critical point is reached when the increasing pressure carries the mass beyond the state of a perfect gas and into the period of declining stellar life. Beyond this stage lie the denser and smaller stars known as "dwarfs," of which our sun, 1.4 times as dense as water, is one. As the shrinkage goes on, the colors that mark the giant state return, first yellow and then through deepening shades of red as the star approaches final extinction.

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[1] Situated on Mount Wilson, California. Address, Pasadena, California.

Knowledge of the distances of these stars, and of their motions across and parallel to the line of sight, has rendered possible the determination of their actual motions in space. It has thus been found that the space velocities of the yellow and red stars, especially the giants, depend upon their absolute luminosities, the fainter stars moving more rapidly than the brighter ones. A decrease in brightness of one magnitude is found to correspond to an increase of about 3 km. per second in the average velocity in space. While the bearing of this result is not yet certain, it probably means that stars of small mass move more rapidly, on the average, than those of large mass. Of the many other important conclusions of this investigation given in the body of the report, one of the most significant is that the stars with large velocities, most of which are of the dwarf class, are moving toward the center of the galactic system. Thus this extensive investigation is leading to conclusions of the most fundamental significance, which are rapidly advancing our knowledge of the structure and evolution of the stellar universe.

In the last annual report the successful application of the interferometer, in the form due to Dr. Anderson, to the measurement with extraordinary precision of the close double star Capella, was fully explained. Dr. Merrill has since continued the measurement of Capella and other doubles, and Professor Aitken has undertaken to apply this method to many of his closest pairs with the 36-inch Lick refractor. Reference was also made to a special interferometer 20 feet in length, built for use on the tube of the 100-inch telescope, which had given sharp fringes when tested by Professor Michelson at its full aperture on certain stars. With this instrument remarkable results have since been obtained by Mr. Pease.

On the night of December 13, 1920, when observing Betelgeuse, he found that the sharpness ("visibility") of the fringes steadily decreased as the interferometer mirrors were separated, until they finally disappeared completely when the mirrors were 10 feet apart. Assuming the mean wave-length of the light of Betelgeuse to be λ5750, the angular diameter is at once found to be 0".047, corresponding to a linear diameter of about 215,000,000 miles.[1] Since that time Mr. Pease has found that the fringes of Arcturus and Antares disappear at mirror separations of about 20 feet and 12 feet, respectively, corresponding to angular diameters of 0″.022 and 0″.040, and linear diameters of about 21,000,000 and 400,000,000 miles. In the case of several other stars, even when the angular diameter is much smaller, distinct decrease in visibility has been observed when the mirrors were separated. In fact, Professor Michelson has made very precise estimates of decreasing visibility for white stars, and has devised a simple auxiliary apparatus for producing comparison fringes of known visibility. Thus, if uncertainties due to variations in seeing can be allowed for, which is still uncertain, it may become possible with the 20-foot interferometer to obtain approximate measures of stars of very small angular diameter.

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[1] These linear diameters may be considerably in error, chiefly because of uncertainty regarding the exact value of the parallaxes of these stars.

The importance of this investigation is obvious, as it has already given beautiful confirmation of Russell's theory, proving the existence of giant stars of enormous size and of mean density about one-thousandth that of atmospheric air. The new method will be developed to the fullest possible extent and applied to all the stars that come within its range.

The third very exceptional event in the progress of the year dates, in its inception, from the origin of the Observatory. At Kenwood on a small scale and at the Yerkes Observatory on a larger one, the writer had utilized laboratory experiments as the necessary means of interpreting astrophysical phenomena. In this respect he simply had followed the example of Huggins, Lockyer, and others, gradually increasing the scale of the instrumental equipment as need and experience developed. A physical laboratory naturally formed part of the original Mount Wilson equipment, and this has proved so necessary to the interpretation of solar and stellar phenomena that it is now being advanced from a secondary to a primary place in the scheme of the Observatory. The importance of taking this step was mentioned in the last two annual reports, and progress has already been made, as the present report indicates, in building up the equipment on the necessary scale.

From the outset this equipment has been planned with special reference to the practical problem of interpreting astronomical phenomena. While it has not been thought wise to limit our physical investigations to such needs, it has seemed equally inadvisable to expand very far into the domain of the investigator who deals primarily with the fundamental laws of physics and chemistry. Thus, in our work on the Zeeman effect, begun for the express purpose of interpreting sun-spot phenomena, it has seemed best not to limit our laboratory studies simply to the lines affected in spots, but also to include other lines and to extend the range of wave-length well into the ultra-violet, beyond the termination of the characteristic spot spectrum. Similarly, in the Stark effect and now in the combined effect of electric and magnetic fields on radiation, we have not adhered narrowly to the viewpoint of the astronomer, but have attacked our problems with the general interests of research in mind, without endeavoring to draw any boundary line between astronomy and physics.

Attractive as the fundamental physical aspects of these problems may be, it is nevertheless plain that their unlimited pursuit by the Observatory staff would result in a scattering of effort and in too great a departure from the paths leading to our primary objectives. It is opportune to consider in the present connection the nature of these objectives and the best means of developing the work of the Observatory in its broader aspect.

At the outset, as the original name of the Observatory indicated, our plan was to base a general study of stellar evolution on an intensive investigation of the sun, the results of which were expected to guide our attack on other celestial objects. The belief that increased knowledge of our nearest neighbor among the stars would aid in the comprehension of remote stellar objects has not been disappointed, as previous reports have shown. But in one important respect it has become necessary to enlarge the scope of our plan. The relationship between physical development, defining the successive stages in stellar life, and the various elements that determine a star's place in the structure of the universe has proved to be much more intimate than the knowledge then available had led us to recognize. Moreover, the various data, such as radial velocity, parallax, absolute luminosity, etc., thus rendered necessary for the interpretation of stellar spectra, were at hand only in the case of a few of the brighter stars. As our work progressed outward toward the remote stars, the importance of including in our scheme an investigation of the structure of the stellar universe, involving observations of stellar parallaxes, radial velocities, etc., became manifest. The results described in the present report are sufficient evidence of the necessity of this policy.

Two great problems of astronomy—the evolution of stars and the structure of the universe—have thus been attacked, but an equally important one has hitherto played only a minor part in the scheme of the Observatory. This is the constitution of matter, which in many cases may be approached even more effectively by the astrophysicist than by the physicist or chemist. Helium, rare on the earth but conspicuous in the solar atmosphere, was first detected there in 1868 and found in a terrestrial source in 1896. The influence of a magnetic field on radiation was visible forty years ago in the spectra of sun-spots, where a great physical experiment, open to observation with the best instruments of that time, was in progress in every spot. Faraday's last experiment, frustrated by inadequate instrumental means, was an attempt to detect the very effect that the magnetic field in spots shows so plainly. To go farther back, the complete Balmer series of hydrogen lines, known in the laboratory only through its four less refrangible members, was photographed by Huggins in the sixties in the spectra of white stars and reproduced with difficulty in the laboratory some years later. To-day we know that nebulium exists in the nebulæ and in at least one star, but no one has succeeded in isolating or even detecting this gas on earth. Scores of other illustrations might be advanced to indicate how often the clue to fundamental physical and chemical problems may be found in the stars, but one will suffice—the remarkable relationship between ionization potentials and certain characteristic phenomena of solar and stellar spectra, pointed out by Saha and already applied by Russell in the case of sun-spots (p. 238).

It is clear, therefore, that the constitution of matter, so richly and abundantly illustrated under the extreme ranges of pressure, of temperature, and of electrical excitation exhibited by the sun and stars, should be raised from a minor to a major position in the astronomer's scheme of research. The equipment of the Mount Wilson Observatory is peculiarly adapted for this purpose; but one essential aid was lacking—the close coöperation of great physical and chemical laboratories, manned, equipped, and endowed with this chief end in view. As already suggested, such laboratories, dealing with the study of the constitution of matter and not primarily with the interpretation of astronomical phenomena, could not properly form a part of the Observatory establishment. They would be equally useful, however, in a neighboring institution sufficiently close at hand to permit intimate daily coöperation. Fortunately, they are now available through the successful activities of the California Institute of Technology, which has been equally appreciative of the possibilities of combined action and has been engaged for years in the development of a general policy in which the present move plays a vital part.

The history of this institution may be of interest here. Established in 1891 as the result of a gift of $50,000 from Amos G. Throop, it was in 1904 a school of nearly 500 pupils, chiefly of elementary, grammar-school, and high-school grades, though two or three were receiving more advanced instruction. Under the presidency of Dr. James A. B. Scherer, appointed in 1908, it gradually altered its policy, gave up its work below college grade, and in 1910 began again, in a new building, with only 31 students, all of them pursuing the courses of a technological school of small size but of high standards. The total assets of the Institute were still very limited, amounting, all told (buildings, site, equipment, and endowment), to approximately $580,000. The plans in view, however, were clear and definite: high standards, more and better humanistic courses than technological schools generally offer, and adequate provision for scientific research, to be ultimately the leading feature of the school. In 1916 a gift of $200,000 was received as an endowment for research in chemistry, and Messrs. Charles W. and P. G. Gates provided a building for a chemical laboratory.

Dr. Arthur A. Noyes, Director of the Research Laboratory of Physical Chemistry and for two years Acting President of the Massachusetts Institute of Technology, was appointed Director of Chemical Research. For several years Dr. Noyes spent three months annually in Pasadena, but in 1919 he resigned from the Massachusetts Institute and removed permanently to California. In that year a further gift of $200,000 was received as an endowment fund to initiate research in physics, and Dr. Robert A. Millikan, Professor of Physics in the University of Chicago, was engaged as Director of Physical Research, spending three months of each year in Pasadena. During the past year several gifts to the Institute, including large additions to the endowment fund and $500,000 from Dr. Norman Bridge for a physical laboratory and library, have permitted the trustees to carry out their original plans. Dr. Millikan has accepted permanent appointment as Director of the Norman Bridge Physical Laboratory and, beginning this autumn, will spend all of his time in Pasadena. As his chief object is to continue his investigations on a larger scale and to build up an important center of research, he prefers not to accept the position of president, left vacant in 1920 by the resignation of Dr. Scherer because of ill health. He will, however, be Chairman of the Executive Council, which will have charge of the administration of the Institute. This will consist of three members of the Board of Trustees, Mr. Arthur H. Fleming, Mr. Henry M. Robinson, and the writer, and three members of the faculty, Messrs. Millikan, Noyes, and Barrett (secretary of the Institute).

These details are given because of the close relationship which will hereafter exist between the Mount Wilson Observatory and the California Institute of Technology. As during the past year, the members of the Observatory staff will meet weekly with the investigators of the Bridge and Gates Laboratories to hear reports on current research and discuss problems of common interest. They will also be invited to attend the courses of lectures to be given at the Institute by eminent men of science, who will include for the coming year Professor H. A. Lorentz of Haarlem, and Professor Paul Epstein, formerly of Leiden and now a member of the faculty of the Institute. Furthermore, a joint study of the constitution of matter and the nature of radiation will be organized, in which the astronomical, physical, and chemical aspects of these problems will be attacked by the members of the three groups immediately concerned.

In assembling the powerful instrumental equipment required for this work, the three laboratories will act in close coöperation. Thus the provision, by the Southern California Edison Company, of a high-tension laboratory on the campus of the Institute, to contain a 1,000-kw. transformer, giving approximately 1,000,000 volts, will render the acquisition of similar apparatus by the Observatory unnecessary. Needless to say, this plant will be of great service in pushing to the highest attainable limit some of the investigations described in this report and others of similar character. The Observatory will also be aided materially by having access to the powerful X-ray apparatus and the large physical library to be installed in the Bridge Laboratory. More important still, constant stimulus and enlightenment will be derived from close association with Dr. Millikan's researches on atomic structure and Dr. Noyes's chemical investigations of problems bearing directly on astronomy. The new step is therefore an epoch-making one in the progress of the Observatory.

Turning to other aspects of the year's work, we may first mention those which bear directly upon this closer alliance with physics and chemistry. For many years certain peculiarities of solar and stellar spectra have baffled all attempts at solution. As an example, it has been impossible to understand why the H and K lines, which certainly belong to calcium, an element of comparatively high atomic weight, nevertheless extend to the highest levels in the solar atmosphere, far outreaching the lines of sodium, magnesium, and other lighter elements. Dr. Megh Nad Saha, Assistant Professor of Physics in the University of Calcutta, has recently offered an explanation which appears to be generally applicable to the interpretation of many of the most puzzling phenomena of solar and stellar spectra. According to this view, the H and K lines are the enhanced lines of a calcium atom which has lost one electron, whereas the fundamental line of neutral calcium is $\lambda 4227$. In the higher levels of the chromosphere, where the ionization, which is only partial at the higher pressures of lower levels, becomes complete, neutral calcium and hence the $\lambda 4227$ line disappears, while H and K, representing the ionized atoms, remain as conspicuous lines. The D and b lines of sodium and magnesium are due to the neutral atoms, which are not present at high levels, and the lines corresponding to the ionized atoms of these and other elements fail to appear because they lie in the extreme ultra-violet, with the possible exception of $\lambda 4481$ of magnesium. Space is lacking to give further details, but Dr. Saha has already pointed out many possible applications of his theory, and others will rapidly develop. In evidence of this, attention is called to the important results obtained by Dr. Henry Norris Russell, Research Associate of the Observatory, who has extended the theory to the case where atoms of several kinds are present, and tested it in a preliminary study of the spectra of sun-spots (p. 240). Among the interesting results of this work is the discovery in the sun of rubidium, shown by the presence in the spot spectrum of two lines in the infra-red, as predicted by Saha. A general attack on solar, stellar, and laboratory spectra from this point of view, in which Dr. Russell and other members of the staff will take part, is being organized. In this connection it is expected that the determination of certain ionizing potentials and the study of many other fundamental aspects of the question will be undertaken at the California Institute.

Another problem calling for the joint activity of the Institute and the Observatory is that which involves the combined effect of electric and magnetic fields on radiation. The nature of this effect has been sought by the writer because of his desire to decide conclusively whether the existence of electric fields can be detected in sun-spots or other solar phenomena, and also because of the important bearing of the effect on the structure of the atom. If an electric field exists in a sun-spot, the radiating particles within it must be subjected simultaneously to the influence both of the electric field and the magnetic field of the spot. No evidence of the Stark effect has been detected in sun-spot spectra, and the weakening of the enhanced lines and other evidences of low ionization seem to indicate that a strong electric field can not be present. It has nevertheless been thought advisable to undertake in our laboratory an investigation of the effect of the combined fields, the preliminary results of which are given in this report (p. 288). In this work, done with the efficient aid of Mr. Sinclair Smith, we have fortunately had the use of the powerful coreless magnet designed by Dr. Anderson (p. 288), which gives a field of 33,000 gausses with a current of 4,000 amperes, and is admirably adapted for the insertion of our special quartz vacuum-tubes within the uniform magnetic field. This magnet is also especially adapted for the study of the inverse Zeeman effect with the aid of an electric furnace designed by Dr. King for this purpose (p. 286).

Dr. King's regular investigations of furnace spectra have dealt for the most part with the emission lines of manganese, scandium, cadmium, yttrium, neodymium, and zirconium, and the absorption spectra of iron and the alkali metals. Between λ2795 and λ6605, 270 manganese lines have been classified on the basis of their temperature variations between 1,560° and 2,400° C.; 307 scandium lines have also been classified, and the characteristics of the enhanced lines and of those strengthened at low temperatures have been determined. As the enhanced lines are the only ones that are strong in the solar spectrum, it is of interest to learn that these are produced in the furnace at moderate temperatures, in some cases as low as 2,250° C. The low-temperature lines, absent for the most part from the solar spectrum, are naturally strengthened in spots. In the work on absorption spectra it has been found possible at the highest temperatures (3,200° C.) to reverse practically all the iron lines as far as λ6700. Such high temperatures have also rendered it possible to photograph the subordinate series of sodium, potassium, and calcium in absorption, giving improved wavelengths and better values of the series constants.

Dr. Anderson's work on the absorption spectra of electrically exploded iron wires has been continued with high dispersion over the range λ2600 to λ6600. The spectra show great wealth of detail and indicate that all of the absorption lines are displaced toward the violet because of the motion of the absorbing vapor toward the observer. This displacement is, in general, greater for high-temperature than for low-temperature lines, and for this and other reasons it is evident that the special form of condenser needed for the development and extension of this work should be provided as soon as possible (p. 291). The results of the work of Messrs. Anderson and Smith on the discharge of the present large condenser through vacuum-tubes are also very promising (p. 291).

The publication of the wave-lengths of 1,026 iron-arc lines by Messrs. St. John and Babcock marks an important advance in high-precision spectroscopy. Instrumental errors have been largely eliminated by the comparison of photographs taken with five different gratings and with four pairs of interferometer plates, and the agreement indicates that for most of the lines the mean wave-length is accurate to 0.001 A. The results show the serious displacement produced in the standard arc by pole effect, and the consequent necessity of taking exceptional precautions in the comparison of solar and terrestrial wave-lengths (p. 289).

How essential such considerations are is well illustrated by the recent history of the attempts of various spectroscopists to detect the shift of solar lines predicted by Einstein. Several investigators, after making arbitrary assumptions and applying various corrections for pressure shift and motion in the solar atmosphere, have each confirmed Einstein's value. As a matter of fact, no final conclusion seems to be warranted that is not based upon an exhaustive study of pressure shifts, variations with temperature, pole effect, motions in the solar atmosphere, and other phenomena under investigation by Messrs. St. John, Babcock, King, and other members of the Observatory staff (p. 242). Of prime importance in this work is the series of interferometer observations of the wave-lengths of lines at the center of the sun, made by Messrs. Babcock and St. John with the Snow telescope. The lines selected for measurement cover a range of 2,500 A, and are chosen with reference to elements of chief interest in the sun, atomic weight, line intensity, probable level in the solar atmosphere, absence of close companions, etc. (p. 245). In conjunction with this investigation Mr. Babcock's interferometer study of the pressure displacements of selected iron lines under a small range of pressure is of great importance. A differential method of observation and the precautions taken to eliminate pole effect have led to results of the highest precision (p. 292).

Several of the most important additions to the equipment of our Pasadena laboratory have already been mentioned. Messrs. Nicholson and Pettit have also made an extended investigation of various forms of thermo-couples for laboratory and astrophysical uses. The most successful of these is a tellurium-silver couple, used in vacuo, which has given excellent preliminary results. Further studies will soon determine the best arrangement of this apparatus for the purposes in view (p. 286).

Closely connected with these problems is the question of the constancy in position of the telluric lines, often used as standards in the solar spectrum. A long series of very careful measures of oxygen and water-vapor lines by Dr. St. John and Mr. Babcock has failed to confirm the large changes in wave-length found by Pérot. They conclude that these lines are practically constant in position, and are thus of great value as standards (p. 245). Messrs. St. John and Nicholson, using a dispersion of 3 angstroms per millimeter, have been able to prove beyond question that both oxygen and water-vapor lines are absent from the spectrum of Venus. With the high dispersion employed, the relative velocity of Venus and the earth was sufficient to separate completely from the telluric lines any corresponding lines originating in the atmosphere of Venus. The absence of oxygen and water-vapor lines raises the question whether equal dispersion would show them in the spectra of other planets (p. 248). Professor Russell points out that St. John's proof of the absence of oxygen in the atmosphere of Venus is in harmony with the slight indications of oxygen in sun-spots, and the abundance of unoxidized material in volcanic gases and in the earth's crust. A planet, if formed from the outer layers of the sun, would contain little oxygen. This suggests that the oxygen in the earth's atmosphere may be a product of vegetation in geological times (p. 241).

From a discussion of 56 spectrograms of Venus and 41 of the sky, Mr. Nicholson finds that the discrepancies between the wave-lengths of Venus and sky lines may be attributed to the effect of atmospheric refraction (p. 247).

Another piece of related work is the investigation of the spectrum of an iron arc on Mount Wilson by Dr. Anderson and Mr. Babcock, as observed from the Pasadena laboratory at a distance of 7 miles, equivalent to 1.4 atmospheres. Under poor conditions of observation the spectrum has been photographed as far as λ2740, although the solar spectrum ends at λ2890. The work will be continued under better atmospheric conditions (p. 292). In this connection reference may also be made to the identification by Dr. Merrill of additional air-lines in the spark spectrum in pure oxygen (p. 292).

The effective wave-length of sunlight has been determined with high precision at Pasadena and on Mount Wilson by Mr. Anderson, with results indicating that it is practically constant from the zenith down to an altitude of 30°. By using this value it becomes possible to calculate with sufficient accuracy from color indices the effective wavelength of the light of any given star, as required in the reduction of interferometer measures of its angular diameter (p. 245).

Mr. St. John's spectroscopic investigations of the solar rotation, which have now been continued for some years, give a mean linear velocity at the equator of 1.93 km. per second, with slight irregular fluctuations. He sees no reason to believe in a progressive change from year to year, and is inclined to attribute differences between observers to systematic errors (p. 241).

Daily observations of the magnetic polarities and field-strengths of all sun-spots have been made, as in previous years, with the 150-foot tower telescope by Messrs. Ellerman, Nicholson, Pettit, Hoge, and Benioff. Special mention should be made of the great spot of last May, which was notable for its size, its position exactly on the equator, its eruptive activity, its mixed polarity, and its connection with the brilliant auroras and violent magnetic storms which occurred while the spot was crossing the disk. All of the evidence favors the view that the terrestrial phenomena were due to the eruptions which took place repeatedly in the area surrounding the spot. Although appearing to the eye as an ordinary bipolar group, the spot was shown by our observations of the Zeeman effect to comprise two large areas of opposite polarity in each of its chief members. As any direct magnetic effect at a distance would thus be largely annulled, the evidence against appreciable influence on the earth, already sufficiently conclusive, is still further strengthened by this interesting case (p. 235).

The writer's study of the nature of sun-spots has included the further examination of the three spot hypotheses outlined in the last report; the search for an electric field, now almost conclusively settled in the negative (p. 288); and the detailed investigation of the Zeeman effect in the spot spectrum. Much evidence may be assembled (p. 237) in support of the deep penetration of the spot-vortex, which would rule out the shallow vortex called for by the second hypothesis. The requirement that the length of the vortex shall be of the same order as the diameter of the spot, which was deduced by Störmer from his theoretical investigation of the direction of the lines of force, is strongly opposed to this hypothesis. Dr. Russell has also shown that to account for the low temperature of spots by expansion, the ascending gases must have come from depths where the temperature ranges from 10,000° to 20,000° C. (p. 240). Detailed investigation of the Zeeman effect in the spot spectrum has involved the measurement, by Dr. H. C. Wilson and Miss Mayberry, of displacements on photographs taken with Nicol and quarter-wave plate of about 6,500 lines in the regions λ3900 to λ4700 and λ5200 to λ5300. The work is being continued by Miss Mayberry and the writer toward the red, about 700 lines beyond λ6100 having been measured thus far. The peculiar displacements of the *p*-components of spot triplets mentioned in previous reports may be due in part, if not exclusively, to the mutual influence of closely adjoining lines rather than to some abnormality of the Zeeman effect; but this question is not yet settled (p. 237).

Mr. Hubble's investigations have dealt especially with the galactic nebulæ and the involved stars, and with non-galactic "globular nebulæ," which are very numerous. These latter objects resemble spiral nebulæ in spectrum and radial velocity, but even the largest of them offer no evidence of spiral structure. The smaller representatives are often indistinguishable from small spirals, but the globular type illustrated by M 87 apparently constitutes a distinct class, which is receiving special study. Many galactic nebulæ and nebulous stars have also been photographed with the 60-inch and 100-inch telescopes. These nebulæ apparently obscure in part the stars beyond or within them, and suggest by their forms the action of repulsive forces emanating from associated stars.

Extended nebulæ and "dark" or obscuring nebulæ are found to cluster about two planes—the galactic circle and the belt of bright helium stars—thus supporting the hypothesis of a local cluster resembling the clouds of the Milky Way (p. 251).

Mr. Hubble's studies of variable nebulæ have been continued with interesting results. Small changes in Hind's variable nebula can apparently be attributed to variations in absorption affecting luminous regions beyond, and the same may be said of N. G. C. 2261, though in this case the involved star appears to exercise some influence in its immediate neighborhood. N. G. C. 7629 showed marked changes, while the involved star R Coronæ Australis was brightening rapidly. Between the nights of August 14 and 16, 1920, a bright envelope, which expanded in three days from 4″ to 12″ in diameter, developed about the star. The highest observed rate of 4″ per day, assumed to represent a wave of illumination traveling outward with the velocity of light, corresponds to a distance of about 290 light years, which is in good agreement with the distance as deduced by two other methods (p. 252).

Mr. Hubble's spectroscopic survey has doubled the number of known gaseous extended nebulæ and more than tripled that of extended nebulæ (p. 253) showing continuous spectra. Reference is made below to his studies of the spectra of nebulous stars and their relationship to those of other stars and nebulæ.

In harmony with previous results for M 33, Mr. van Maanen has obtained definite evidence of outward motion along the arms of the spiral nebulæ M 51 and 81. As possible sources of error now seem to have been excluded, this interesting result may be considered as substantial support for Jean's theory, which indicates that matter should be thrown off from two points of a nebula after it has been reduced by rotation to a lenticular form (p. 255).

Mr. Duncan has photographed a considerable number of nebulæ and star-clusters, and has detected large internal motions in M 1 (Crab nebula), confirming the results of Lampland. These motions are generally outward from the center, and show a maximum displacement of 2″.5 in the 11½ years' interval between the plates. Three new novæ in the Andromeda nebula and two new variable stars in the Trifid nebula have been found on these photographs (p. 258).

The investigation of the spectra and colors of nebulous stars by Mr. Seares and Mr. Hubble has been completed for most of the known objects brighter than the 13th magnitude. Their exceptional color is strikingly illustrated by 17 faint stars involved in nebulosity near *o* Persei, which show an average color excess of over half a magnitude (p. 259). In contradistinction to this effect, probably a scattering by the surrounding luminous nebulosity, Mr. Seares has found no positive evidence that the obscured areas, or "dark nebulæ," in Perseus and Taurus, produce any increased redness of the neighboring stars. Mr. Hubble has photographed an abnormally high percentage of late-type stars in these regions, but most of these are presumably dwarfs lying in front of the obscuring clouds, which are comparatively near us and cut off completely the light of the more distant stars (p. 262).

Mr. Seares and Mr. Hubble have also made an extensive study of the correlation of stellar luminosity with spectral type and color. By plotting absolute magnitudes against spectral types or equivalent color-indices some interesting relationships appear. The curve of modal values for the helium stars runs smoothly into that of the dwarfs. The Cepheids and pseudo-Cepheids of our own system present, in the mean, a correlation of color with luminosity similar to that of the Cepheids and the giant stars in globular clusters. From a corresponding correlation it is also inferred that the stars in the galactic clouds are similar in luminosity to these classes of stars. The frequency curve for stars of all types is in good general agreement with the luminosity and density functions of Kapteyn and van Rhijn (p. 277).

With the aid of data bearing on absolute magnitude, Mr. Seares has determined the mean total masses of visual binaries of the various spectral types. These show the following remarkable correlation with spectral type:

B0, mass = 18; B5, 14; A0, 10; A5, 7; F0, 4.4; F5, 2.7;
G0, 1.7; G5, 1.3; K0, 1.2; K5, 1.1; M, 1.0.

From F0 on the masses in this summary are those of the dwarfs (p. 276). Further reference to this important investigation will be made after the completion of studies still in progress.

Photometric observations by Messrs. Seares, Shapley, Hubble, Humason, and Lindblad have covered a wide range. Mr. Hubble has nearly completed the determination of the photovisual and photographic magnitudes of 250 stars associated with nebulæ and nebulous clusters (p. 259). Mr. Seares has given special attention to the determination of the colors of nebulous stars and the stars in galactic clouds and special fields (p. 263). His color-comparisons of the Selected Areas in the +30° zone with the North Pole is half completed, and the combination of his photographic magnitudes with those of Kapteyn and van Rhijn, made with the assistance of Miss Joyner and Miss Richmond, are practically complete for areas 1 to 67 (p. 261). Mr. Shapley, assisted by Miss Richmond, has finished a survey of the photographic and photovisual magnitudes of about 850 stars in the Pleiades between magnitudes 10 and 15.5. Within this range the members of the cluster are dwarfs of absolute magnitude 5 to 10.5 (p. 261). In connection with the work of the International Committee on Magnitudes, Mr. Seares, as chairman, has made a series of tests of the Mount Wilson photometric scale. These confirm earlier tests and show perfect agreement with Hertzsprung's measures for the interval between magnitudes 6 and 13 (p. 262). A study of the colors of 60 stars in the Pleiades by Mr. Seares has afforded a useful check on the method of reduction and confirmed two anomalous results suspected from other evidence (p. 263).

Reference has already been made to Mr. Seares's investigations of stars in the Galaxy. From these he has derived provisional estimates for the distance of the galactic clouds, which range from 20,000 to 50,000 light-years for the blue stars of apparent magnitude 14 to 15.5. These are minimum values, indicating a scale for our stellar system in harmony with that derived by Mr. Shapley from his studies of globular clusters (p. 263).

Mr. Shapley has continued his work on globular clusters and related problems. The distance of the cluster N. G. C. 7006, previously found to be 220,000 light-years, has been confirmed by a study of its variable stars (p. 265). He has also extended his investigation of the distribution of the stars with reference to the plane of the local cluster and the galactic plane, and finds that the brighter B stars belong to the star-cloud immediately surrounding the sun, while the fainter B stars do not (p. 263).

A relationship discovered by Mr. Shapley between the light-curves of Novæ and certain irregular variable stars suggests that the outburst and variation of Novæ may result from causes such as are active in these variables (p. 265). He has also examined the question whether the changes in geological climates may be due to causes analogous to those that produce the irregular Orion variables, where motion through nebulosity seems to be the source of variation (p. 266). The eclipsing binary SX Cassiopeiæ, studied in association with Mrs. Shapley, is of exceptional interest, because its mean density is of the order of 0.0005 that of the sun. This system actually consists of a very close pair of giant stars, each having a linear diameter comparable with that of Arcturus (p. 266).

The faintest and most distant known variables are 19th magnitude stars in the globular cluster N. G. C. 7006. From an investigation by Mr. Shapley and Miss Mayberry, these objects appear to be typical short-period Cepheids, some of which undergo marked light variations in a few hours (p. 266).

The velocity in space of blue and yellow light, as shown by Mr. Shapley's comparative study of certain variable stars, seems to differ less than one part in a billion (p. 265).

Hugo Benioff has made preliminary tests on stars of a thalofide cell, with direct-current audion amplifier. The following deflections were observed with the 60-inch reflector: β Pegasi (vis. mag. 2.2 to 2.7, type Ma), 52 mm.; ϕ Pegasi (vis. mag. 5.2, type Ma), 4 mm; α Andromedæ (vis. mag. 2.2, type A0p), 5 mm. The deflections seemed to be reliable, and the work is being continued with the expectation of reaching fainter stars (p. 266).

Aided by a new stereocomparator, built in our instrument shop for differential measures of high precision, Mr. van Maanen has continued his trigonometric determinations of parallaxes and proper motions. The total number of parallaxes completed to date is 144. New measures of the parallaxes of five long-period variables, combined with a previously known value for o Ceti, give mean absolute magnitudes of +1.5 and +6.5 at maximum and minimum, respectively. Theories of variability must therefore recognize the giant character of such stars at maximum (p. 258). A negative parallax was derived for the variable nebula N. G. C. 2261, in harmony with Mr. Hubble's view that its rapid apparent changes must be due to progressive variations of illumination rather than actual motion of matter (p. 252).

Some of the most important of the stellar spectroscopic results of the year have already been mentioned, but much more has been accomplished in this vigorous and successful branch of the Observatory's work. The radial velocities of 253 stars have been measured by Messrs. Adams and Joy and Miss Burwell and Miss Brayton. Twenty spectroscopic binaries have been discovered, and the elements of the orbits of 8 spectroscopic binaries have been completed, 7 by Mr. Sanford and 1 by Mr. Duncan (p. 269).

Much attention has been devoted to variable stars of various types. Ten cluster variables give values from +70 to −180 km. for the "velocity of the system," without apparent relationship with distance from the Galaxy. Mr. Joy has determined the orbit of the variable S Antliæ which proves to be of the Algol type. The orbit of the Cepheid variable X Cygni has been investigated by Mr. Duncan on the basis of the binary hypothesis. The dark and bright lines of the Cepheid variable W Virginis show marked differences in the radial velocities (p. 268). Remarkable changes in the spectrum of o Ceti were observed near minimum, including a curious asymmetry of the hydrogen lines, such as would result from an angular separation of $0''.2$ in the sources producing them. Peculiar changes were observed in the spectrum of R Scuti. Eight long-period variables with Cepheid characteristics were found to have bright lines (p. 274). The spectra of the companions of Capella, Antares, and Sirius have been photographed, and much miscellaneous spectroscopic work has been done (p. 274).

Mr. Merrill has now determined 101 radial velocities of long-period variables, 91 of which resemble *o* Ceti, while 10 have spectra of a new type. 83 of these stars, of the Md (*o* Ceti) type, give from their bright lines the following values for the solar motion: V=56 km., A=274°, D=+44°. The average residual velocity of 31 km. is the greatest known for stars of any spectral type (p. 269). Several additional nebular lines have been found in R Aquarii; the displacements of the nebular and stellar lines are being studied. The prominent bright lines of the Md stars have been observed after maximum in the spectrum of R Cygni, a variable with very different absorption spectrum. Humason and Merrill have discovered during the year more than 50 stars with bright $H\alpha$ line (p. 275).

The radial velocities of 28 R-type stars have been found by Mr. Sanford to range from +60 to −400 km. The algebraic mean freed from solar motion is −17 km. (p. 269).

Mr. Hubble has photographed the spectra of about 150 nebulous stars between 10.5 and 14.0 magnitude. Bright-line stars in extended nebulæ are nearly all of types Oe5 and B0, while those giving an absorption spectrum are B1 or later, averaging about B4. The central stars in six large planetary nebulæ have spectra intermediate between the Wolf-Rayet and Oe5 types. Combining these results with those of Wright on smaller planetaries, we have the following sequence of types for stars involved in galactic nebulæ: small planetaries, probably Wolf-Rayet; large planetaries, between Wolf-Rayet and Oe5; extended bright-line nebulæ, Oe5 to B0; extended nebulæ with absorption spectrum, B1 to A3. This suggests the possibility that only the earliest and hottest stars may be capable of exciting bright-line emission in surrounding nebulosity. Near a critical type, about B1, the bright lines fade rapidly and an absorption spectrum soon predominates, perhaps representing the reflected light of the star, as indicated by Slipher. This tentative suggestion is being thoroughly tested (p. 254).

The study of spectra of Novæ, old and recent, has been continued by Messrs. Adams and Joy. Except for decreased brightness of the ring relatively to the central star, the extraordinary spectrum of Nova Aquilæ 1918 has changed but little during the year. Nova Cygni 1920 showed important changes within two weeks, both in type and velocity. T Coronæ, the Nova of 1866, was found to have an absorption spectrum closely resembling that of a typical giant Ma star, with bright hydrogen and λ4686 lines (p. 274).

Kapteyn has developed during the year a theory of the arrangement and motion of the entire stellar system. From his results on the distribution of stars, he derives the attraction of all the stars on any point within the system, expressed in terms of the attraction of a star of average mass. Systematic motion of the stars is necessary to produce equilibrium. Such motion, parallel to the plane of the Milky Way, is actually observed in the star-streams. A rotatory motion around the axis toward the pole of the Milky Way is therefore assumed (p. 283).

The formula derived from the kinetic theory of gases for the barometric determination of altitudes is then applied to the stars lying along the rotation axis, on the assumption that their velocities are approximately distributed according to Maxwell's law. This leads to values of the average effective mass of a star ranging from 2.2 at 198 parsecs to 1.4 at 1,660 parsecs.

The centrifugal forces in the plane of the Milky Way are so determined as to give the same average effective mass for regions of equal star density in this plane and on the rotation axis. The linear tangential velocities corresponding to these forces vary but little with the distance. For the greater part of the system they are practically constant and equal to 19.5 km. The direction of rotation is indeterminate. If two groups are assumed to be moving in opposite directions, their relative velocity is 39 km., which agrees closely with the observed relative velocity of these two star streams.

Although admittedly speculative in many particulars, the value of a theory of star-streaming, giving results in harmony with observation, is obvious. Both the weak and strong points of the theory are fully discussed in a Contribution soon to be published by this Observatory.

Professor Russell has extended Saha's theory of ionization in solar and stellar atmospheres to the case where atoms of several kinds are present. He finds that the proportions of ionized atoms for different elements depend only upon the temperature, though the elements of lower ionization potential are always most highly ionized, those that have lost one electron giving ordinary enhanced lines, and those that have lost two electrons giving "super-enhanced" lines, such as certain silicon and oxygen lines studied by Fowler (p. 238).

Professor Russell has also found Majorana's theory of the absorption of gravitation by matter to be untenable when tested by the motions of the moon and planets and the phenomena of the tides. Majorana's experimental results, if confirmed, may be explained as a change of mass caused by the mutual influence of two bodies (p. 285).

Dr. Bertil Lindblad, of the University of Upsala, who has spent nearly a year at the Observatory, has made an important extension of the method of determining the absolute magnitude of a star from its spectrum. The continuous spectrum of A and B stars between λ3895 and λ3907, when compared with the adjoining region toward the red, is less intense in stars of low luminosity than in brighter stars. By finding the exposure ratio necessary to give equal photographic impressions for these regions the absolute magnitude is obtained. The method has been applied to the stars of several moving clusters, with results for parallax in good agreement with previous determinations.

The "cyanogen" bands have also been found to show marked increase of absorption in the more luminous stars, thus affording another measure of absolute magnitude. The effect is greatest for stars of types G5 – K2 and decreases considerably toward G0 and Ma. Giants and dwarfs as faint as apparent magnitude 13.5 may be distinguished on slitless spectrograms by this method (p. 271).

Mention should be made of two important pieces of work, not done under the direct auspices of the Observatory. One of these is the repetition on Mount Wilson of the Michelson-Morley experiment by Professor Dayton C. Miller, of the Case School of Applied Science. This fundamental investigation, which should show whether increase in altitude above sea-level has any appreciable effect on the perception of possible relative motion of the earth and the ether, is still in the preliminary stage and will be continued by Professor Miller. The second is the initiation by Dr. H. O. Wood of the seismological work in Southern California which is being organized by the Carnegie Institution of Washington. In both cases the Observatory has been able to assist in various ways.

For many years visitors have been admitted daily to the Observatory museum of astronomical and physical photographs on Mount Wilson, and certain of the instruments have been shown by Mr. W. P. Hoge, the assistant in charge. During the past year about 10,000 visitors have seen the 100-inch telescope. We have long hoped to arrange for an open night, on which celestial objects could be shown to the public with one of the large telescopes. In view of the great height and small capacity of the observing platforms of the 100-inch telescope it is clearly unsafe to permit their use by the public. The Cassegrain focus of the 60-inch telescope is easily accessible, however, and this instrument has accordingly been arranged for use by the public on Friday evenings. Tickets are issued without charge to those who send their requests to the office of the Observatory in Pasadena.

STAFF.

The Director has devoted much time to the project of developing research in physics at the California Institute of Technology in coöperation with the Observatory. He has also undertaken an investigation of the combined effect of electric and magnetic fields on radiation and continued his solar researches. Dr. Walter S. Adams, Assistant Director, has given most of his attention to his investigations in stellar spectroscopy. Professor Frederick H. Seares, superintendent of the Computing Division and editor of the Observatory publications, has advanced his stellar researches in various directions. Dr. Arthur S. King, superintendent of the Physical Laboratory, has pursued his work with the electric furnace. Dr. Charles E. St. John has continued his studies on the solar rotation, the spectrum of Venus, and the wave-lengths of solar and terrestrial lines. Dr. J. A. Anderson has investigated the effective wave-length of sunlight and starlight, and the spectra of explosive discharges, and continued his tests of the ruling machine with Mr. Jacomini. Dr. Harlow Shapley, who has gone on with his work on variable stars and globular clusters, left for the Harvard College Observatory in March on a year's appointment. Mr. Harold D. Babcock has given most of his time to the comparison of solar and laboratory wave-lengths and the measurement of pressure shifts. Mr. Francis G. Pease, in addition to his work on instrument design, has measured star diameters with the 20-foot interferometer. Dr. Paul W. Merrill has continued his investigations on long-period variable stars and the spark spectrum of air. Mr. Ferdinand Ellerman has made regular solar observations and served as Observatory photographer. Dr. Adriaan van Maanen has continued his investigations on trigonometric parallaxes and on proper motions of stars and motions in spiral nebulæ. Professor Alfred H. Joy, secretary of the Observatory, has taken part in the stellar spectroscopic work. Dr. John C. Duncan, who has spent a year at the Observatory, has made photographs of nebulæ and joined in stellar spectroscopic observations. Dr. Seth B. Nicholson has continued his observations of the sun and Venus, and has begun laboratory experiments with thermopiles. Dr. Gustav Strömberg has continued his work in stellar spectroscopy, with particular reference to theoretical investigations. Dr. R. F. Sanford has also taken part in the stellar spectroscopic work. Mr. Edwin P. Hubble has been engaged in the photographic and spectroscopic study of nebulæ and nebulous stars. Dr. Bertil Lindblad, of the University of Upsala, has been at the Observatory as volunteer assistant since October and has carried on investigations dealing with the determination of the absolute magnitudes of faint stars by spectroscopic methods. Dr. H. C. Wilson, of Carleton College, spent the months between September and June at the Observatory and devoted his time to the measurement of lines in the sun-spot spectrum and a number of stellar spectra. Mr. Edison Pettit, who joined the staff on September 1, has taken part in the solar observations and in the work with thermopiles. Mr. W. P. Hoge, night assistant with the 60-inch telescope, has joined in the stellar spectroscopic observations. Mr. Milton Humason, night assistant, has made photographic and stellar spectroscopic observations with the 10-inch telescope and other instruments. Mr. Edison Hoge has taken part in the solar observations and served as assistant photographer. Mr. Hugo Benioff assisted during the summer in the solar observations and continued his experiments with the thalofide cell. Mr. Sinclair Smith has been part time assistant in the Pasadena laboratory throughout the year.

Professor J. C. Kapteyn, now of the Leiden Observatory, Research Associate of this Observatory, has continued his stellar investigations in Holland. Professor A. A. Michelson, of the University of Chicago, Research Associate, has continued at Mount Wilson his researches with the interferometer and on the velocity of light, and has undertaken there a study of the relative motion of the earth and the ether by a new method. Professor Henry Norris Russell, of Princeton University, recently appointed Research Associate, spent two months at the Observatory, where he carried on a variety of studies dealing with the Majorana gravitation effect, Saha's ionization theory, oxygen in planetary atmospheres, and other subjects.

Professor Dayton C. Miller, of the Case School of Applied Science, repeated the Michelson-Morley experiment on Mount Wilson in the spring. Dr. Harry O. Wood, Research Associate of the Carnegie Institution of Washington, began his seismological investigations in Southern California with temporary headquarters at the Pasadena office of the Observatory.

Of the Computing Division, Miss Ware and Miss Miller have continued to assist Dr. St. John. Miss Burwell, Miss Brayton, Miss MacCreadie, and Miss Shumway have been engaged with the investigations in stellar spectroscopy. Miss Richmond, Miss Joyner, and Miss Mayberry have assisted Mr. Seares and Mr. Shapley in photometric measures and reductions. Mrs. Marsh has assisted Mr. van Maanen with trigonometric parallaxes and reductions of measures on spiral nebulæ, while Miss Keener has given her time to the work of the Physical Laboratory. Miss Mayberry has also assisted the Director, and Miss Brayton has given some time to the measurement of laboratory spectrograms. Miss Connor has remained in charge of the library and has aided with the editorial work.

Mrs. Harlow Shapley, volunteer assistant, continued her work in collaboration with Dr. Shapley. Messrs. Clyde R. Keith and F. L. Hopper, of the California Institute of Technology, assisted Dr. Merrill in his laboratory studies during part of the year. Dr. K. S. Gibson, of the U. S. Bureau of Standards, worked for a few weeks with the Koch apparatus.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

INSTRUMENTS.

Except for some minor improvements of the interferometer and spectrograph used with the Snow telescope, and the development of the thermopiles for solar research described in connection with the work of the laboratory, no important changes have been made in the equipment for solar observations.

SOLAR PHOTOGRAPHY.

During the year ending August 31, 1921, the following solar photographs were taken with the 60-foot tower telescope by Messrs. Ellermann, Nicholson, Pettit, E. R. Hoge, and Benioff.

Photoheliograms of 6.5-inch image, 319 on 308 days.
Spectroheliograms with 5-foot spectroheliograph (*Hα*, entire 6.5-inch disk), 184 on 184 days.
Spectroheliograms with 13-foot spectroheliograph (K and *Hα*, 2-inch disk and prominences; portions of 6.5-inch disk with *Hα* and with monochromatic light from continuous spectrum), 1,087 on 297 days.

Photographic observations with the Snow and 150-foot tower telescopes are included in the following statements.

SUN-SPOT ACTIVITY.

A total number of 168 groups was observed during the calendar year 1920 as against 295 during 1919. There were 8 days in 1920 on which no sun-spots were visible at the time of observation, 2 in April, 2 in August, and 4 in September. The 4 in September were consecutive days, making the longest quiescent interval since 1915. There was, no doubt, considerable activity on the visible part of the sun even on these days, because an active period immediately followed this calm period. The accompanying table gives the average number of groups observed per day each month:

Month.	Daily number.	Month.	Daily number.
January	3.0	July	3.1
February	4.4	August	2.1
March	3.7	September	2.1
April	2.0	October	4.2
May	3.2	November	2.3
June	3.5	December	3.4

The average latitude of all groups observed during the year was 11°, 1° degree less than the average for 1920.

SUN-SPOT POLARITIES.

Daily drawings of the solar image given by the 150-foot tower telescope, showing the approximate positions, polarities, and field-strengths of sun-spots, have been made as in previous years by Messrs. Ellerman, Nicholson, Pettit, E. R. Hoge, and Benioff. Photographs of spot spectra have also been taken, and special attention has been given by Mr. Nicholson to a study of the direction of the lines of force in different portions of the spots. The following table, prepared by Mr. Nicholson, gives the polarities of all spots observed in the northern and southern hemispheres of the sun during the calendar year 1920:

Hemisphere.	Polarity.		
	Regular.	Irregular.	Undetermined.
North	79	5	4
South	73	1	6
Whole sun	152	6	10

GREAT SUN-SPOT OF MAY 1921.

The sun-spot which appeared at the east limb on May 8, while not of the very largest size, was a very exceptional group, especially during the time of reduced solar activity. The sun's equator passed longitudinally through the spot, and intermittent eruptions near its principal members were photographed throughout the period of observation. A violent terrestrial magnetic storm, accompanied by brilliant auroras, began just when the preceding edge of the calcium flocculi surrounding the group reached the central meridian and continued with fluctuating intensity for several days. The very active eruptive region following the largest umbra was on the meridian when the third or most intense phase of the magnetic storm began. On May 16, at $4^h\ 10^m$ G. M. T., there was a great outburst in this region, coinciding very closely with a sudden break in the terrestrial magnetic record, which rose to a maximum 30 minutes later, when an $H\alpha$ spectroheliogram showed the eruption to cover an enormous area.

In the Director's first paper (1908) on the existence of magnetic fields in sun-spots, he pointed out the improbability of any direct influence of these fields on the earth. Subsequently, Schuster, assuming an extreme spotted area, the same polarity for all spots, and a length of vortex (separation of poles) equal to an entire solar diameter, calculated that their collective magnetic effect at the earth could not exceed 0.1 mm. displacement on the Greenwich scale. When actual areas, mixed polarities, and short vortices are taken into account, the probability of any appreciable influence is still further reduced. In the present case the mixed polarities of the two principal components of the group, which superficially resembled a typical bipolar spot, would be an important factor.

SUN-SPOT HYPOTHESES.

Such curiously mixed polarities as those of the large May spot must be carefully considered in the elaboration of any hypothesis of bipolar spots. Each major member of the group was divided into two parts, of opposite polarity, so that in a sense the entire spot might be regarded as a combination of two bipolar groups. Important abnormalities remain, however, and these will afford much opportunity for study. The polarity rule holds with very few exceptions in both hemispheres of the sun, but it is not surprising that it should be departed from exactly on the equator, especially in a region remarkable as a seat of violent eruptions.

The origin of spots at considerable depths below the surface of the photosphere is indicated by (1) the prior appearance of eruptions, which probably originate in viscous regions far beneath the surface; (2) the law of the spot variation in latitude during the sun-spot cycle and the variable length of the period; (3) the reversal of the magnetic polarity of spots at the minimum; (4) the reappearance of spots in the same region; (5) the 27-day magnetic period, possibly indicating the presence of invisible spots; (6) the increase in strength of the magnetic field with decreasing level; (7) the observed inclination of the lines of force in the umbra and penumbra; (8) the existence of small spots with fields more intense than their area would warrant, perhaps connected with a large vortex below; (9) the irregular form of the penumbra, indicating that it is at a considerable distance above the spot vortex. If a single spot represents a long columnar vortex, its lower extremity, especially if deflected toward the east by a lower velocity of solar rotation within the photosphere, may turn up to the surface of the photosphere, thus forming a spot which should follow (on the east) the primary spot in most cases. A bipolar group, in which the following member appears and disappears, may represent such a case. It should be noted in this connection that a magnetic field, of the expected polarity, is sometimes observed in such a group when the second spot is not visible. In many bipolar groups, however, it is hardly conceivable that the two principal members, especially when large in diameter and close together, can represent the opposite extremities of a semicircular vortex-ring. The difficulty is increased in cases of mixed polarity, such as that presented by the May spot.

SUN-SPOT SPECTRUM.

The study of the Zeeman effect in the sun-spot spectrum is a long and difficult task, partly because of the large number of lines involved (over 5,000), and also because of the incomplete separation of the vast majority and the lack of sufficient laboratory data for those that are clearly resolved. The measures made by Dr. H. C. Wilson, during a residence of several months at the Observatory, and by Miss Mayberry and the writer, who are continuing the work, therefore relate for the most part to the displacements of unresolved lines on adjoining strips of the compound quarter-wave plate, used with a Nicol prism when the spectra were photographed in the second order of the 75-foot spectrograph of the 150-foot tower telescope. At the violet end, where the measures were begun, these displacements are small, but they increase greatly toward the red. When the mean of a considerable number of lines in each region is taken, it is interesting to observe the increase of shift with wave-length, both for mixed lines and for the more homogeneous material afforded by single elements, though these are complicated by the effects of level and the varying laboratory separations corresponding to individual lines.

Abnormal lines offer another interesting and important subject of study, which is also being pursued by the writer and his associates. As Mr. St. John has pointed out, the peculiar displacements of the *p*-components in certain spot triplets may result partially (perhaps even exclusively) from such mutual influences of closely adjoining lines as he has observed in his studies of the solar spectrum. This question is being attacked from several different points of view with the hope of clearing it up completely.

The results of a further attempt to determine whether measurable electric fields exist in sun-spots are described below (p. 291).

EXPANSION IN SUN-SPOT VORTEX.

To account for the low temperatures of sun-spots by expansion of the ascending gases in the vortex, Mr. Russell finds that it is necessary to assume that the latter come from a depth at which the temperature is at least 10,000° C. It is probable that the temperature at the bottom of the ascending part of the vortex is at least 20,000° C., and that the expansion in volume on rising to the surface is more than forty-fold.

IONIZATION IN SOLAR AND STELLAR ATMOSPHERES.

The theory of ionization in solar and stellar atmospheres, developed by Dr. M. N. Saha, has been extended by Professor Russell to the case where atoms of several kinds are present. Taking into account the existence of a common dissociation product (electrons) it is found that—

(1) If in any stellar atmosphere the ratio of the number of atoms which are ionized to those which are not is formed for different elements, these ratios will bear proportions to one another which depend only upon the temperature and not upon the pressure or the relative abundance of the different elements.

(2) The elements of lower ionization potential are always most highly ionized. The range of temperature and pressure within which both ionized and non-ionized atoms can coexist in sensible proportions

is extended by the presence of other elements in the case of an element of easy ionization, but diminished in the case of an element harder than the average to ionize.

(3) When multiple ionization takes place, by the successive removal of two (or more) electrons from the atom, the number of successive stages of ionization in which a sensible proportion of atoms can simultaneously exist is only two (at least under any conditions which are likely to be met with).

The ordinary (flame or arc) lines are absorbed by non-ionized atoms, the enhanced lines by ionized atoms, and certain "super-enhanced" lines by double ionized atoms. Many facts connected with the spectral sequence among the stars are explainable upon these principles. For example, the fact that the arc lines disappear in class B before the "super-enhanced" lines appear is a direct consequence of (3).

The following results have been obtained by a test of the theory in sun-spot spectrum:

The principal lines of rubidium, λλ7800.29 and 7947.64, which are absent in the solar spectrum, appear in the spot spectrum as diffuse lines of intensity 1 and 0, respectively, show strong Zeeman effect, and are very similar in character to the lithium line at λ6708.

The lines of the principal series of potassium are much strengthened in the spot spectrum. The infra-red pair of sodium at λλ8183, 8194 is also much strengthened.

The lines of the subordinate series of potassium, lithium, and rubidium appear neither in the sun nor in spots.

All these phenomena are in excellent accordance with the theory of Saha, who predicted most of them. Rubidium appears to be so completely ionized in the sun that there are not enough neutral atoms left to absorb the ordinary lines, except at the lower temperature of the spots. Lithium, however, should be less ionized than sodium, and the absence of its lines in the spectrum of the sun can be explained only on the assumption that very little of the element is present.

The alkaline earths show a similar behavior. Barium, which is the most easily ionized, appears in the solar spectrum mainly by its enhanced lines; and the presence of even the most prominent line due to the neutral atom (λ5535) appears to be doubtful both in sun and spots. The lines of zinc, which have a high ionization potential, are much weakened in spots.

IONIZATION OVER FACULÆ.

On the Bohr theory of atomic structure, radiation of the normal type occurs only when an electron falls from one orbit to another of lower potential energy. The ordinary enhanced lines of an element are thought to be produced when the atom is ionized, that is, when one electron has been removed completely. Saha has developed an expression for the relative proportion of ionized to un-ionized atoms as a function of temperature and pressure, the proportion increasing with rise of temperature and decrease of pressure. For elements whose ionization potentials are known, he deduces the state of ionization in the solar atmosphere for assumed values of the temperature and pressure. He suggests that over the faculæ, which are considered to be regions at temperatures higher than that of the photosphere, the spectrum, owing to the increased temperature, should become similar to the spectrum of a star at a temperature higher than that of the sun. This would be shown by an increase in the intensity of the enhanced lines, proportional to the increase in the number of ionized nuclei. Some preliminary spectrograms of faculæ obtained by Mr. St. John show changes in the intensity of the enhanced lines in agreement with these deductions, the spectral type changing in the direction G0 to F, as indicated by the accompanying table.

Behavior over faculæ.

Wave-length. Rowland.	Element.	Intensity.	Class.	Effect.
4306.078.....	Ti	4	Flame.	No change.
4443.976.....	Ti	5	Enhanced.	Strengthened.
4468.663.....	Ti	....	Enhanced.	Strengthened.
4501.445.....	Ti	5	Enhanced.	Strengthened.
4518.198.....	Ti	3	Flame.	No change.
4527.490.....	Ti	3	Flame.	No change.
4572.156.....	Ti	6	Enhanced.	Strengthened.
4215.703.....	Sr	5	Enhanced.	Strengthened.
4607.510.....	Sr	1	Flame.	Weakened.
4246.996.....	Sc	5	Enhanced.	Strengthened.
4325.152.....	Sc	4	Enhanced.	Strengthened.
4400.555.....	Sc	3	Enhanced.	Strengthened.
4352.083.....	Mg	5	Flame.	Weakened.
4481.298.....	Mg	0	Enhanced.	Strengthened.
4481.515.....	Mg	0	Enhanced.	Strengthened.
4571.275.....	Mg	5	Flame.	Weakened.
4491.570.....	Fe	2	Enhanced.	Strengthened.
4508.455.....	Fe	4	Enhanced.	Strengthened.
4520.397.....	Fe	3	Enhanced.	Strengthened.
4522.802.....	Fe	2	Enhanced.	Strengthened.
4554.211.....	Ba	8	Enhanced.	Strengthened.

It is evident that in ionization phenomena we have a new means of attacking solar problems. On the other hand, solar observations will supplement laboratory methods. Little is known of the ionizing potenials of elements outside the first and second columns of the periodic table. For other elements, such as iron and titanium, a promising approach to the question is through their behavior in regions of widely different solar temperatures and pressure as compared with that of elements whose ionization potentials can be investigated under laboratory conditions. For any element the changes depend upon the degree of ionization over the photosphere and the susceptibility to excitation, and these, moreover, vary for the different lines.

The identification of the enhanced line of magnesium, λ4481, in the solar spectrum seems to be definitely settled. King discovered its duplicity in the tube-arc spectrum, and Fowler has accurately determined the wave-lengths of the components. The two weak solar lines are much strengthened over faculæ and weakened in spots. They are therefore enhanced lines. Solar spectrograms of high dispersion yield the same separation and relative intensity as the best laboratory plates. The solar wave-lengths are 0.007 A longer than the terrestrial wave-lengths. The identification is as certain as for any other solar line.

OXYGEN IN PLANETARY ATMOSPHERES.

The absence of any evidence that oxygen is present in the atmosphere of Venus seems surprising, in view of the abundance of oxygen in the earth's atmosphere, but it falls into line with several other facts pointed out by Russell.

(1) The oxygen triplet at λ7772–75 is practically extinguished in the spot-spectrum, though the lines of titanium and the bands of titanium oxide are strong in spots.

(2) The igneous rocks of the earth's crust contain so much ferrous oxide that the whole of the free oxygen of the atmosphere would not nearly suffice to convert it into ferric oxide.

(3) Volcanic gases appear, on the whole, to contain a good deal of unoxidized material (carbon monoxide, free sulphur, etc.).

All these facts can be explained on the assumption that the outer layers of the sun (from which it now appears probable that the planets were formed by eruptions at some remote period) do not contain enough oxygen to combine with all the metallic elements present. A planet in its initial state would then have an incompletely oxidized surface and an atmosphere devoid of free oxygen.

The oxygen of the earth's atmosphere may be an organic product, given off by vegetation during geological time, and balanced by an accumulation of carbonaceous organic residues in the sedimentary rocks. The latter would correspond to a layer of coal covering the earth's surface about 2 feet thick, which does not appear to be an impossible amount.

SOLAR ROTATION.

The observations by Mr. St. John now cover 7 years. The mean value of the linear velocity at the equator is 1.93 km. per second, with small and irregular variations from year to year. For the year of spot maximum, 1917, the value is about 1.5 per cent above the mean. Little significance, however, can be attributed to this small deviation for the 7-year mean until the observations at higher latitudes are fully taken into account. When spots are plentiful and forming rapidly, there is greater liability to local and superficial disturbances. The significance of the higher value as indicative of a change in the period of rotation is also lessened by the fact that the values for the years immediately preceding and following are slightly below the average for the 7 years, though in both years spots were numerous.

The discrepancies between the earlier measures of Duner, Halm, and Adams and the results from this long series are an outstanding feature of the problem of solar rotation. The mean of their values is 2.06 km. per second (1900–1908); the mean for Plaskett and Schlesinger is 2.01 (1911–1913); the mean for the present Mount Wilson series is 1.93 (1914–1920). Evidence that we are not observing an actual change in the period of the sun's rotation may be stated as follows:

1. There is no progressive change in 7 years when observing conditions remain uniform.

2. The internal agreement for each observer is good. The results for two series by Adams are 2.06 and 2.05 km. per second; for three series by J. S. Plaskett they are 2.01, 2.02, and 2.01. For the current 7-year series the mean deviation per year is less than 1 per cent. This raises the question of systematic effects depending upon the observing conditions.

3. A continuous retardation of the order indicated for the 20 years during which spectrographic observations have been applied to the problem appears unacceptable from any point of view.

The present program contemplates the continuance of the observations through a complete sun-spot cycle, the gathering of material for a detailed study of rotation in the northern and southern hemispheres, and the simultaneous use of duplicate instrumental equipment for separating the influences of personal equation from those depending upon the instruments.

For the present, observations are in the main confined to the region of λ6300, in which atmospheric lines are available for eliminating instrumental disturbances, for avoiding faulty illumination of the grating by the different prisms, and for studying the occurrence and influence of local disturbances in the reversing layer.

DISPLACEMENT OF SOLAR LINES AND RELATIVITY.

Because of numerous fragmentary attacks upon this question, the situation is becoming more and more involved and unsatisfactory, as the following brief summary by Mr. St. John shows:

The Cyanogen Lines.

From the line λ4197, the unsymmetrical head of the second band, Pérot (C. R., July 26, 1920, 229), after applying a correction for an assumed *downward* movement in the solar atmosphere and for a negative pressure shitt of the cyanogen-band lines, the latter approximately equal in magnitude to the shift required by relativity, finds that the sun-arc displacement is that predicted by the theory. On the other hand, Dr. Birge, after applying a correction for an *upward* movement and assuming *no* pressure shift for the band lines, finds, from the published data for 2 lines in the λ3883 band, lines which he considers free from superposed lines of other series, that the sun-arc displacement for these lines is approximately that required by the relativity hypothesis. Though from the series view these lines are suitable, their character in the solar spectrum is such that the measures are unreliable. Grebe and Bachem assumed *no* radial movement of the solar vapors and *no* pressure shift for the band lines, but applied a correction for a supposed *asymmetry* of the arc-lines, and found approximately the Einstein effect (Phys. Gesell. Verh. 21, 1919).

Investigations on the lines of the cyanogen band made in our laboratory by Mr. Babcock do not confirm the displacement to the red in passing from atmospheric pressure to vacuum, as found by Pérot, but indicate a normal displacement with pressure of perhaps 0.0001 A per atmosphere. Mr. King finds that the lines of the cyanogen band belonging to different series vary in relative intensity with change in furnace temperature. In a recent article (Science, Apr. 15, 1921), Dr. Birge calls attention to the extensive overlapping of lines of the different series. In view of this superposition of lines, of the changes in relative intensity with temperature, and of the line-density in the solar spectrum, it appears that the cyanogen band is not well adapted for a definitive test of the theory.

OTHER ELEMENTS.

From the magnesium line λ5172, Pérot (C. R., Apr. 25, 1921), after correcting his observed shift between the arc and the sun's center for a *centripetal* movement in the solar atmosphere of 1.57 km. per second and reducing the arc wave-lengths to zero pressure, finds a difference between sun and arc in approximate agreement with the Einstein requirement. The lines of the magnesium triplet in the green are, however, subject to a marked pole-effect and three independent investigations at Mount Wilson by Messrs. Adams, Joy, and St. John, fail to show the centripetal motion of the solar vapors used in Pérot's reduction of his observations. Fabry and Buisson find (C. R., Apr. 25, 1921) that the differences between the arc wave-lengths of iron reduced to vacuum and the wave-lengths at the sun's *center* are of the order of the Einstein effect. They conclude that the differences, sun minus arc, are perfectly interpreted by assuming the Einstein effect to be the sole cause of the displacement of the Fraunhofer lines. They assume zero pressure in the solar atmosphere, but disregard the limb-center shifts, which they formerly referred to an increase in pressure of 7 atmospheres in passing from the center to the limb and which, if taken into account, would give displacements in excess of the Einstein requirement. Pérot applies a *large correction*, 0.027 A, for centripetal motion, and finds the difference between the wave-length at the *limb* and the arc in vacuum to agree with the Einstein effect. Fabry and Buisson apply *no* correction for radial movement of the solar vapors and find the differences between the wave-lengths at the *center* and the arc in vacuum to agree with the Einstein requirement, but not the differences between the wave-lengths at the limb and the arc.

Owing to the different and even inconsistent corrections applied to the observed sun-arc displacements, the resulting approximate agreement with the deductions from the Einstein theory fails to carry conviction. In view of the situation in which this important question now stands, it appears necessary, in order to reach a definitive conclusion, to carry out an extensive program on sun-arc displacements, including observations at center and limb and covering the widest possible range in wave-length and line-intensity; to obtain, in short, a reliable body of data as a basis for statistical discussions. The problem must be envisaged as a whole and not in detached portions and a consistent and probable rôle found for the gravitational effect if the theory of relativity is to find confirmation in the displacement of Fraunhofer lines.

In addition to data for disentangling the causes involved in the displacement of the solar lines, the program includes a study of the relative consistency of the solar wave-lengths at the center and limb, the determination of a series of solar standards in the international system, and observations on a limited spectral region in common with the Kodaikanal Observatory.

WAVE-LENGTHS OF LINES AT THE CENTER OF THE SUN.

The determination of wave-lengths at the center of the sun in terms of iron-arc standards has been continued by Messrs. St. John and Babcock with the interferometer in conjunction with the Snow telescope. Further experience in the use of this equipment has resulted in such minor improvements and changes of technique as the limitations of the instruments have required, and has confirmed previous judgment of its usefulness. Observations covering the range λ4000 to λ6500 have been made at intervals throughout the year. The reduction of the plates, though incomplete, confirms as heretofore the values of the solar wave-lengths found with grating spectrographs. A list of lines has been carefully selected for measurement upon these photographs, special reference being given to (1) elements of paramount interest in the sun; (2) range of atomic weight; (3) individual line intensity; (4) probable vertical distribution in the solar atmosphere;

(5) freedom from close companion lines; and, finally, to other considerations, such as their usefulness in forming a framework for a new table of solar wave-lengths. For economy of time it is planned to confine the measurements for the present to this restricted list of lines, leaving a large amount of material available for future study.

EFFECTIVE WAVE-LENGTH OF SUNLIGHT.

In astronomical applications of the interferometer, the results of a measurement will always be given in the form $\alpha = Kx\lambda$, where α is an angular distance, K a quantity determined by the constants of the instrument used, x the setting made, and λ the mean or effective wave-length of the light of the body studied. K can always be determined with great accuracy; experience up to date indicates that x can be determined to 1 per cent or less. In order to utilize the full efficiency of the instrument, we must therefore know λ to a few tenths of 1 per cent.

Given certain data, such as the spectral-energy distribution of the object under investigation, the transmission of the atmosphere for different wave-lengths, the sensitiveness of the eye to different colors, and a number of optical constants of the instrument employed (difficult to determine), the effective wave-length λ can be calculated. At present such a calculation is possible only for the sun, and even here an experimental check is highly desirable on account of the number of constants entering into the calculation.

An experimental determination of the value λ for sunlight after reflection from two clean silver surfaces has been made by Mr. Anderson, both in Pasadena and on Mount Wilson. The observations on Mount Wilson show that the changes in the effective wave-length between zenith distance 0° and 60° are practically negligible, amounting to only 0.3 per cent. Under ordinary observing conditions on Mount Wilson, the wave-length may therefore be regarded as a constant for a given object, provided its zenith distance does not exceed 60°. The accuracy of the experimental determinations of λ for the sun appears to be of the order of 0.1 per cent.

A method of determining the value of λ for any star was also devised and tested, but was found to have a probable error of roughly 2 per cent, due principally to the effects of seeing. It is unnecessary, however, to employ this method, for since we now know the value of λ for the sun, the correction for a given star may be computed with sufficient accuracy from its color-index or from its temperature as given by Wilsing.

STABILITY OF ATMOSPHERIC LINES.

The observations of Pérot (C. R. 160, 549, 1915) raised the question of the constancy of the wave-lengths of the atmospheric lines. He deduced from his observations on a line in the B band of oxygen that the wave-length increased from morning to noon and decreased from noon to evening, and referred this apparent change in wave-length to a recession of the absorbing centers from the earth with a velocity of 3.15 km. per second. Owing to the importance of atmospheric lines as standards in the solar spectrum, an extended series of observations has been carried on by Messrs. St. John and Babcock at Mount Wilson.

On the B Band at λ6800.

Grating spectrograms of the sun's center were taken in February 1919 at sunrise, noon, and sunset, on which 8 oxygen lines were measured with the Rowland wave-length of the solar lines as standards. After corrections for the motions of the earth, the mean, noon *minus* morning and evening, is +0.002 A. To correspond with Pérot's results, the changes from morning and evening to noon should have been +0.043 and +0.039 A.

In June 1919, 28 lines of the B group were measured with the interferometer, using international wave-lengths of the solar lines as standards. The deviations from the mean for all observations are as follows:

Time.		Altitude.		Deviation.
hr.	*min.*			
9	8..	50°	35′	−0.0005A
10	32..	67	17	+0.0010
12	36..	75	38	−0.0013
3	40..	41	14	+0.0001
5	11..	22	25	+0.0010

Within the limits of error, the wave-lengths from these observations of the 28 lines are independent of the altitude of the sun. To agree with Pérot's observations, the noon wave-lengths should exceed those at 5 o'clock by +0.043 A.

On the *a* Band at λ6300.

Grating spectrograms of the sun's center, with international solar wave-lengths as standards, give for the mean of 8 lines in the *a* band:

Date.	Time.	Altitude.		λ6291+
Aug. 3, 1911....	6 a. m.	9°	50′	.213A
June 7, 1919....	6 a. m.	12	30	.214
Feb. 26, 1919....	12 m.	46	45	.215
Mar. 8, 1919....	12 m.	50	35	.212
June 9, 1919....	12 m.	78	38	.216
Aug. 3, 1919....	6 p. m.	9	54	.213
June 9, 1919....	6 p. m.	12	38	.217

The mean of noon measures is λ6291.2147, and of the morning and evening measures λ6291.2142. To confirm Pérot's observations, the noon measures should have exceeded the low-sun measures by 0.043 A. This result was checked by a direct comparison between the iron-arc and the oxygen lines on May 27, 1920, in the Pasadena Laboratory, and on June 16, 1920, on Mount Wilson.

On the Water-Vapor Lines at λ5900.

In 1921, 12 lines of water-vapor were measured with high and low sun. Because of their weakness at times of high sun on Mount Wilson the measures were difficult. The solar lines were used as standards. The deviations from the mean for high and low sun are:

Time.	Date.	Altitude.	Deviation.
Morning..	1921. Mar. 3.	16°	−0.001A
Noon....	1921. Mar. 2–Mar. 24.	61 20′	+0.001
Evening..	1921. Mar. 1–June 24.	13	0.000

For recession, as found by Pérot for the oxygen line, the morning and evening measures should have been 0.038 and 0.041 A less than for the high sun.

In these observations oxygen lines of the *a* band have been referred directly to iron-arc lines by both grating and interferometer, and indirectly through solar standards obtained by direct comparison. From the agreement the following conclusions seem to be justified:

1. The wave-lengths of the atmospheric lines are practically constant.
2. In view of possible convection currents, the wave-lengths of the solar lines at the center of the sun are also remarkably constant.
3. The international wave-lengths of the solar standards used are determined to a high precision.

WAVE-LENGTH OF SKYLIGHT AND OF SUNLIGHT REFLECTED FROM VENUS.

From the discussion of 56 spectrograms of Venus and 41 of the sky, Messrs. St. John and Nicholson find that after all known corrections for velocity have been applied, the observed differences between the wave-lengths in skylight and in sunlight reflected from Venus at various phases can be well represented by the empirical formula

$$\Delta\lambda 10^3 = 1.3 - 8.5\,\frac{\cot h}{D}$$

where D is the semidiameter of the planet in seconds of arc and h its altitude at the time of observation. The formula is derived from the following considerations: A correlation with altitude is shown by spectrograms taken at both high and low altitudes on the same night, the plates at the lower altitude giving the shorter wave-lengths. A variation with altitude suggests atmospheric refraction, and hence cot *h* is used as one of the independent variables. Dispersive refraction at altitudes of 5° and 10° displaces the photographic image relatively to the visual image very appreciably. This leads to unsymmetrical illumination of the slit, the degree of asymmetry depending upon the diameter of the image relative to the width of the slit. Twenty-nine plates were secured at the last elongation of Venus with a blue ray-filter in the guiding telescope and more are being taken at the present elongation. Measures of these plates indicate that when the photographic image is symmetrically placed on the slit the discrepancies in wave-length disappear.

When the observations are corrected for the above systematic displacements the differences between morning and evening series are less than their probable errors. Consequently they give no indication of a correction to the assumed parallax, 8″.80, or of a rate of rotation more rapid than that found by Slipher. The high declinations of Venus at the present elongation offer exceptionally favorable conditions for further investigations on rotation, as it will be feasible to obtain plates in the red, with the advantages of working with longer wave-lengths and of using the fixed oxygen lines as standards of reference.

ABSENCE OF OXYGEN AND WATER-VAPOR LINES FROM THE SPECTRUM OF VENUS.

Investigations on the presence of water-vapor and oxygen in planetary atmospheres have in the past been made with a dispersion so low that the lines of the atmospheric bands were integrated. Further, the observations were confined to changes of intensity. The spectrum of Venus on a scale of 3 A per mm. has now been compared by Messrs. St. John and Nicholson with the sky spectrum from λ3900 to λ6900. These observations were made when the relative velocity of Venus and the earth was so large that lines originating in the atmosphere of Venus should have been completely separated from the lines due to the earth's atmosphere, the relative displacement being 0.25 A. Solar lines of intensity 00 and 000 are present in the spectrograms, but among the lines originating in the atmosphere of Venus there is no trace of the water-vapor lines at λ5900 or of the oxygen lines in the a and B bands at λ6300 and λ6900. The only water-vapor and oxygen lines present are those of the terrestrial atmospheric lines. These definitely negative results in the case of Venus will make it of interest to obtain spectrograms of Mars and Jupiter on the same scale.

RESEARCHES ON STARS AND NEBULÆ.

OBSERVING CONDITIONS.

Records compiled by Mr. Hoge, showing the working time of the 60-inch telescope at Mount Wilson for the past 9 years, indicate that the available observing weather for the year ending August 31, 1921, was slightly above the normal amount.

Observations were carried on during all of 192 nights and a part of 99 nights. On 74 nights no observations could be made on account of the weather. The telescope was in use 65 per cent of the total night time. The tables give statistics for each month, the conditions of seeing (on a scale of 10), and the wind velocity.

Seeing.		Wind.	
Scale.	No. of nights.	Velocity.	No. of nights.
1	65	High.........	17
2	43	Brisk.........	20
3	55	Moderate.....	58
4	67	Light.........	128
5	50	Calm.........	120
6	18	....	....
7	4	....	....

Meteorological records kept at the Observatory show a total precipitation for the year of 34.09 inches, which is about normal. Total

Observing record of 60-inch reflector.

Month.	Hours of darkness.	Hours clear.	Hours cloudy.	Hours lost silvering and repairs.	Hours exposure time.	Observations.		
						All night.	Part of night.	None.
1920.								
September......	295	248	47	10	166	21	6	3
October.........	336	232	104	1	178	20	6	5
November......	330	214	116	....	160	17	5	8
December.......	346	180	166	....	127	9	15	7
1921.								
January........	346	151	195	....	112	7	13	11
February.......	308	144	164	....	144	14	8	6
March..........	324	172	152	....	126	9	14	8
April...........	286	189	97	....	127	13	12	5
May...........	266	118	148	....	68	9	9	13
June...........	230	212	18	8	130	24	3	3
July............	255	235	20	....	135	24	6	1
August.........	269	244	25	....	169	25	2	4
Totals........	3,591	2,339	1,252	19	1,645	192	99	74
Mean for 9 years.......	....	2,309	1,277	....	1,632	193	91	81

snowfall 48 inches. Mean temperature 54°; maximum 94°, July 7. Minimum 14°, February 15. Average wind velocity, 10.4 miles per hour; maximum velocity, 60 miles per hour, February 22.

RESEARCHES ON NEBULÆ.

Mr. Hubble's chief subject of study during the year has been the galactic nebulæ and the stars involved therein. Since the Milky Way is not always in position for observation, a particular class of non-galactic nebulæ has also been chosen for investigation. Four-hundred and ninety-two plates were taken during the year, representing 500 hours of actual exposure on 122 separate nights. The longest exposure was 19 hours on the ρ Ophiuchi region, made on four nights with the 15° objective prism on the 10-inch Cooke lens.

The non-galactic objects, which have been designated as "globular nebulæ," are more numerous than those of any other class. The brightest and largest of them, such as M 49, 60, and 87, show no trace of spiral structure, although their spectra and radial velocities are of the same character as those of the spirals. M 87, at least, has a large number of faint stars, none brighter than about the 19th magnitude, clustering around its borders. The appearance is not that of a typical star-cluster, although it approximates this more closely than it does the appearance of a spiral.

The smaller members of the class become more numerous with decreasing size and brightness until they fade into the general mass of faint blotches on the photographs, which can hardly be distinguished from star images. Many of these will undoubtedly prove to be spirals when greater magnification can be employed, and some will become spindles when longer exposures bring out the ansæ. An uncertain percentage, however, should remain in the class of M 87, for the sequence in size is complete to the limits of the telescope.

To gather information on this subject, certain rich fields of small non-galactic nebulæ have been selected, and these are being photographed with the 10-inch, 60-inch, and 100-inch telescopes with comparable focal ratios and exposure times. Classification of nebulæ appearing on these plates should give some indication as to the relation between class and scale. Photographs are also being made with a single telescope and different exposure times, in an effort to correlate class with density of the image. On nights of the finest definition, plates of long and short exposures are made with the 100-inch reflector to study the minute structure of the largest and brightest globular nebulæ. Those photographed to date are:

M 49, 60, 84, 86, and 87.
N. G. C. 524, 4278, 4742, and 5826.

The investigation is proving of considerable interest, but conclusions are not yet definitive.

Direct photographs of the following galactic nebulæ and nebulous stars have been made with the two reflectors:

100-INCH.

B. D.	+30°540
I. C.	348
Uncatalogued nebula:	$\alpha\ 4^{h}\ 14^{m},\ \delta+28°5'$
N. G. C.	1555
B. D.	+1°1001
B. D.	+1°1005
N. G. C.	2045
Uncatalogued nebula:	$\alpha\ 6^{h}\ 3^{m},\ \delta+18°42'$
B. D.	+23°1301
N. G. C.	2261
N. G. C.	6334
I. C.	4601
N. G. C.	6523
N. G. C.	6726-7
N. G. C.	6729
Planetaries.	
N. G. C.	246
N. G. C.	2818
N. G. C.	6720
C. D.	−32°14673
N. G. C.	7009
N. G. C.	7662

60-INCH.

B. D.	+64°13
N. G. C.	281
B. D.	+50°596
B. D.	+29°565
B. D.	+31°597
N. G. C.	1624
I. C.	2087
B. D.	+28°645
N. G. C.	2023
I. C.	345
Comet nebula:	$\alpha\ 6^{h}\ 3^{m},\ \delta+18°\ 42'$
N. G. C.	2175
B. D.	−6°1415
N. G. C.	2183-5
B. D.	−23°5285
N. G. C.	2261
B. D.	+1°1503
N. G. C.	6914
N. G. C.	7129
B. D.	+57°2309
	+67°1332
N. G. C.	7365
δ Cephei (no nebulosity detected).	

These galactic nebulæ usually show a marked obscuration of stars lying within or beyond them. Another general impression gained from inspection of these plates and others is that the forms and structure of galactic nebulæ are influenced largely, if not chiefly, by repulsive forces emanating from involved or associated stars; at least, the forms are interpreted more readily on a basis of repulsion than on one of attraction.

The 10-inch Cooke astrographic lens and the small cameras have been used to study the distribution of extended nebulæ and areas of obscuration. A double distribution of these objects has definitely been established. They condense about two planes—the galactic circle and the belt of bright helium stars. This fact supports the hypothesis of a local cluster and emphasizes its similarity with the Milky Way clouds.

Three small patches of obscuration have been located in galactic latitudes as high as 30° to 37°. Additional evidence confirms Mr. Hubble's former conclusion that the division in the Milky Way in the Aquila-Ophiuchus region is due to great clouds of dark nebulosity.

Polarization tests have been made on several nebulæ with the apparatus employed by Mr. Babcock in his work on the polarization of the night sky. Positive indications were obtained in the case of the Merope nebulosity, but certain questionable points make it desirable to repeat the observations with a new grating in front of the calcite crystal before final conclusions are formulated.

A neodymium-chloride filter prepared by Mr. Anderson has given promising preliminary results with objective prism spectra. This work is being carried on in the hope of using such a filter for radial velocities of the approximately stellar nuclei of certain non-galactic nebulæ.

VARIABLE NEBULÆ.

N. G. C. 1555.—Mr. Hubble has obtained three long, two moderate, and three short exposures of Hind's Variable Nebula with the 100-inch telescope. The long exposures show a wealth of detail, both of illumination and absorption, within a circular area 3 minutes of arc in diameter, about T Tauri as a center. Very small changes in relative brightness have occurred, mostly in the brightest portion south following the star, which can be attributed to areas of absorption cutting out luminous detail. The short exposures show at least three small flares jutting out from T Tauri, south preceding, south following, and to the north. The first is the brightest and registers in 15 seconds on Seed 30 plates. No change has been detected in these details, although it must be understood that definite conclusions can be drawn only from plates made with unusually good seeing. There was no great change in brightness of T Tauri itself during the period covered by Mr. Hubble's plates. The exterior nebulosity showed marked changes as compared with a plate made by Mr. Pease with the 60-inch in 1913.

N. G. C. 2261.—Ten photographs were made during the year, but observing conditions were not always good. Obvious changes occurred, but not on so large a scale as those of the previous year. All observed changes can be accounted for by obscuring clouds wandering over a permanent background of luminous nebular detail, together with an occasional brightening and fading of the nebulosity close about the star at the apex—R Monocerotis. R itself did not vary appreciably during the year.

N. G. C. 6729.—Forty spectrograms on 25 nights were made with the 100-inch reflector during the year. Two runs of several successive nights each were secured, one when the star R Coronæ Australis was brightening rapidly, and the other when the variable was practically stationary at the top of its curve. Only minor changes were noted during the latter run. Rapid changes, however, occurred while the star was increasing in brightness; and these, as in the case of N. G. C. 2261, can be interpreted as the temporary obscuration of a permanent background of luminous detail, together with an intense brightening of nebulosity in the immediate neighborhood of the star. Obvious changes within 24 hours were observed.

Between the nights of August 14 and August 16, 1920, a bright envelope developed around R Coronæ Australis that looked reddish to the eye. Its diameter increased as follows: Aug. 13, 4″; Aug. 14, 5″; Aug. 15, 8″; Aug. 16, 12″; Aug. 17, 12″; Aug. 18, 11″; Aug. 19, 10″. The measurements are rough and subject to uncertainties due to varying atmospheric conditions at the great zenith distance at which the object culminates. Assuming the phenomenon to be a wave of illumination moving with the velocity of light, the most rapid radial growth, about 2″ per day, would correspond to a distance of about 290 light-years. The probable absolute magnitudes of four nebulous stars in the same dark area as the variable nebula indicate a distance of 300 light-years. Distances of this order would require that the moving area of obscuration referred to above travel with the velocity of light. This velocity would correspond to a maximum possible distance of 330 light-years.

Plates made in June 1921 show changes in brightness of faint luminous details, some 90″ preceding the nucleus, a region not obviously connected with the variable nebula. The spectrum of R Coronæ Australis seems not to be of the nova type, as suggested by Slipher (Lowell Bull., No. 81), but is rather like that of T Tauri, except that the bright lines of hydrogen and iron are reversed asymmetrically, and no bright H and K lines have been found. There is, however, a strong bright $H\alpha$ line.

N. G. C. 3550 and I. C. 48.—These nebulæ have been suspected of variability, the latter on the authority of Barnard. Both prove to be spirals. N. G. C. 3550 has a faint star close to the nucleus. If the observed changes in brightness are real, they might be accounted for on the assumption that novæ appeared in the nebulæ.

N. G. C. 7662.—Barnard announced the variability of the nucleus of this planetary some years ago. Photographic and photovisual observations made here give no indications of variability during the year.

Spectra of Nebulæ.

Long exposures by Mr. Hubble with objective prisms on the 10-inch Cooke lens and with the smaller cameras have added to the list of objects whose spectra were known 13 planetaries, 13 extended nebulæ with emission spectra, and 25 extended nebulæ with continuous spectra. Of these objects, 3 planetaries, 6 emission and 5 continuous-spectrum nebulæ were listed in last year's report. The survey has doubled the number of gaseous extended nebulæ previously known, and more than tripled that of extended nebulæ showing continuous spectra.

The planetaries are

I. C.	289	C. D.	−32° 14673
I. C.	2003	N. G. C.	7048
N. G. C.	2818	I. C.	1470
N. G. C.	6072	N. G. C.	7635
C. D.	−29°13998		

and the uncatalogued objects

$\alpha=17^{h}37.0^{m}$	$\delta=-24°\ 39'$ (1920)
17 50.4	−21 44
19 0.0	−33 17
23 22.0	+57 45

Extended nebulæ with emission spectra are

N. G. C.	281	N. G. C.	2024
I. C.	59, 63	N. G. C.	2237
N. G. C.	1491	N. G. C.	2359
N. G. C.	1499	N. G. C.	5128
N. G. C.	1624	N. G. C.	6357
I. C.	405	N. G. C.	7635
I. C.	423		

N. G. C. 7635 appears to be a planetary involved in an extended nebula. There is some suggestion that this is a case of actual collision. I. C. 434, the Bay Nebula south of ζ Orionis, gives an emission spectrum. This fact was previously determined by Max Wolf (Astronomische Nachrichten, v. 180, 152), who unfortunately concealed the matter by giving a wrong catalogue number—N. G. C. 2023, a nebula which has a continuous spectrum.

The extended nebulæ giving continuous spectra are

N. G. C.	1333	N. G. C.	2247
I. C.	348	I. C.	4592
N. G. C.	1579	I. C.	4601
I. C.	2087	I. C.	4603
N. G. C.	1788	I. C.	4605
I. C.	2118	N. G. C.	6726-7
N. G. C.	2023	N. G. C.	6914
N. G. C.	2183	N. G. C.	7129
I. C.	446	I. C.	5146
I. C.	447		

and the uncatalogued objects

$\alpha = 4^h\ 14^m$	$\delta = +28^\circ\ 2'$ (1920)	
4 22.1	+24 32	
5 45.5	+ 1	Brightest part of the great "spiral" in Orion.
6 3.1	+18 42	

Nebulosity about B. D. −12° 1771

Nebulosity about π Scorpii.

The spectroscopic observations of stars involved in nebulosity referred to on page 273 establish a sequence in the types of the stars in galactic nebulæ as follows:

1. Small planetaries	Stars involved, probably Wolf-Rayet.
2. Large planetaries	Stars involved, between Wolf-Rayet and Oe5.
3. Extended emission nebulæ	Stars involved, Oe5 and B0.
4. Extended continuous-spectrum nebulæ	Stars involved, B1 to A3.

The overlap between groups is extremely small and is confined to nebulæ showing peculiar spectra.

The intimate relation between the types of nebular spectra and of the stars involved demands that one be considered a consequence of the other, or that both be due to a common cause. It suggests that one source of nebular luminosity may be found in some influence emanating from associated stars that fall within certain ranges of spectral type, and hence probably of effective temperature. On this basis the earliest and hottest stars alone would excite bright-line nebular luminosity.

Near a critical type, B1 or a fractional subdivision earlier, the bright lines fade rapidly and a continuous or absorption spectrum quickly predominates. Slipher has shown that the absorption spectra of several extended nebulæ agree with the spectra of the stars involved, and this suggests that the luminosity of extended nebulæ having absorption spectra is due largely to reflection of starlight. The fact that bright lines fade so smoothly into a brightening continuous spectrum as the stellar type advances, and that nebulosity around the few known cases of late-type nebulous stars averages considerably fainter than that around stars of earlier types, further suggests the possibility of an excitation which produces continuous spectrum, decreasing with the temperature of the involved stars, superposed on the reflected illumination of the nebulæ. This question can be studied through color-indices of the nebulæ, and attempts are being made to gain the necessary information.

NEBULOUS STARS.

The investigation of the spectra and colors of nebulous stars by Mr. Seares and Mr. Hubble has been continued, and results for most of the known objects brighter than the 13th magnitude are complete. An excess of color over that corresponding to the spectrum of the star is almost always present, though to a varying degree. The most remarkable case is that of the fainter stars near *o* Persei, many of which are involved in the nebulosity I. C. 1985 or its outlying masses. The average color excess for 17 stars is over half a magnitude, and for several of them it amounts to 0.8 or 0.9 mag. Broadly speaking, those closest to the center of the nebula show the largest excess of color. As usual, the stars are of early type, mostly B's with a few A's. Assigning absolute magnitudes in accordance with the luminosity curves of Professor Kapteyn, we have for the mean parallax of the group $0''.0045 \pm 0''.0003$. The spectroscopic parallax of the nearby nebulous star B. D. +31°597 is $0''.005$. I. C. 1985 and the luminous nebulosity surrounding B. D. +31°597 are presumably associated with the obscuring material that fills this part of the sky, and it is therefore probably not accidental that the two parallaxes are the same.

INTERNAL MOTIONS IN SPIRAL NEBULÆ.

In the last report mention was made of the measures of the spiral nebula M 33 by Mr. van Maanen. The results were derived from a pair of plates taken with a 10-year interval at the 25-foot focus of the 60-inch reflector. The earlier plate was secured by Mr. Ritchey, the new one by Mr. Duncan. Measures by Mr. van Maanen of two photographs of the same object taken by him at the 80-foot focus with an interval of 5 years have given strong corroboration of the earlier results.

A new stereocomparator was built during the year, in which considerable improvements have been effected as compared with the Zeiss instrument. After testing, it was put into regular use in April 1921; the results are very satisfactory. With this instrument Mr. van Maanen has measured two other spiral nebulæ, M 51 and M 81. For each object the plates covered intervals of 11 years. The older plates were taken by Mr. Ritchey, the later ones by Mr. Duncan.

These two nebulæ show results analogous to those found for M 101 in 1916 and for M 33 in 1920. The displacements in all cases seem to correspond better with a motion along the arms of the spirals than with a rotation. The radial components, in the mean, are 39 per cent of the rotational components, while the total displacements agree in direction, within the limits of the measurement, with the arms of the spirals.

The results now available practically exclude the possibility that they are due to any source of error in the telescope or the measuring instrument, for the photographs were taken partly at the 25-foot focus and partly at the 80-foot focus of the 60-inch reflector, and partly with the Crossley reflector of the Lick Observatory; and, further, they have been measured partly with the old and partly with the new stereocomparator, while some measures have also been made with an ordinary measuring machine, all of which give similar results.

Accepting the measured displacements as real motions, we find the best explanation of the results in Jeans's theory, matter being thrown off from two points of a nebula after it has attained a lenticular form.

MISCELLANEOUS PHOTOGRAPHS OF NEBULÆ AND CLUSTERS.

During the year Mr. Duncan has obtained 134 photographs of the following nebulæ, clusters, and miscellaneous objects:

N. C. G. 224, M 31 Andromeda nebula.
N. C. G. 598, M 33 Trianguli, spiral.
N. C. G. 869, h Persei, open cluster.
N. C. G. 884, χ Persei, open cluster.
N. C. G. 891, Andromedæ, spiral on edge.
N. C. G. 1952, M 1 Tauri, Crab nebula.
I. C. 418 Leporis, planetary nebula.
I. C. 423 Orionis, octopus-like nebula.
N. C. G. 1976, M 42, Orion nebula.
N. C. G. 1977, nebula around *c* Orionis.
N. C. G. I 434 etc., south of ζ Orionis.
N. C. G. 2024, following ζ Orionis.
N. C. G. 2068, M 78 Orionis.
N. C. G. 2043, Camelopardalis, pinwheel spiral.
N. C. G. 2841, Ursæ Majoris, spiral.
N. C. G. 3031, M 81 Ursæ Majoris, spiral.
N. C. G. 3184, Ursæ Majoris, spiral.
N. C. G. 3184, Ursæ Majoris, spiral.
N. C. G. 3226–7 Leonis, double spiral.
N. C. G. 3242 Hydræ, planetary.
N. C. G. 3550 Ursæ Majoris, many small nebulæ.
N. C. G. 4038–9 Crateris, remarkable spiral.
N. C. G. 4254, M 99 Virginis, spiral.
N. C. G. 4736, M 94 Canum. Ven., spiral.
N. C. G. 4872 etc., Comæ. Many small nebulæ.
N. C. G. 5194, M 51 Canum. Ven., large spiral.
N. C. G. 5457, 101 Ursæ Majoris, large spiral.
N. C. G. 6218, M 12 Ophiuchi, globular cluster.
N. C. G. 6514, M 20 Sagittarii, Trifid nebula.
N. C. G. 6523, M 8 Sagittarii.
N. C. G. 6705, M 11 Scuti, open cluster.
N. C. G. 6720, M 57 Lyræ, ring nebula.
N. C. G. 6822 etc., remarkable group in Sagittarius.
N. C. G. 6853, M 27 Vulpeculæ, dumb-bell nebula.
N. C. G. 6946 Cephei, pinwheel spiral.
N. C. G. 6960 Cygni, network nebula.
N. C. G. 7006 Delphini, globular cluster.
N. C. G. 7078, M 15 Pegasi, globular cluster.
N. C. G. 7293 Aquarii, Harding's helical nebula.
N. C. G. 7492 Aquarii, globular cluster.
N. C. G. 7662 Andromedæ, planetary.

Dark Markings:

Barnard 72 Ophiuchi, S-shape.
Barnard 86 Sagittarii.
Barnard 92 Sagittarii.
Barnard 133 Aquilæ.

Miscellaneous:

The Pleiades.
Neptune.
Nova Persei No. 2 (1901).
Nova Aquilæ No. 3 (1918).
Nova Lyræ.
Nova Cygni (1920).

The photographs of M 31 (Andromeda Nebula) include 17 plates of about 1 hour's exposure taken primarily for detecting novæ. This purpose was also held in view in photographing the other spirals. A 9-hour exposure on M 31 with the 100-inch telescope was made to show as accurately as possible the form of the nebula and to serve for a future study of internal motion.

Plates of N. G. C. 1952 (M 1), 2403, 3031 (M 81), 4254 (M 99), 4736 (M 94), 5194 (M 51), 5457 (M 101), 6514 (M 20, Trifid), and 6946 were taken for the purpose of studying possible internal changes by comparison with earlier plates. An hour's exposure on the Ring nebula with the 100-inch telescope shows certain details which do not seem to appear on other photographs, notably a radial structure in the winding streamers.

The following objects were found to possess special interest:

(1) The bright and dark nebulæ near ζ Orionis. The photograph of I. C. 434 brings out with great prominence the dark cloud, Barnard 33. There is evidence of four distinct types of nebulosity in the region.

(2) N. G. C. 4038–9. A small bright spiral of extraordinary form, already noticed by Mr. Hubble on a plate made by him with the 10-inch Cooke lens. Photographs with the 100-inch telescope show the central part in detail, and, in addition, two faint curved streamers of a length four or five times the diameter of the bright part of the nebula.

(3) N. G. C. 1977. A well-known nebula whose details are well shown on a plate taken with the 100-inch reflector.

(4) A region in Coma Berenices with N. G. C. 4872 central, in which Curtis has counted 249 small nebulæ in an area 38′ by 39′ on a plate made with the Crossley reflector. On a plate of 4 hours' exposure with the large reflector Mr. Duncan has counted, within a circle 30′ in diameter, 319 nebulæ, 115 stars, and 206 faint objects of undetermined character.

(5) The dark markings, Nos. 72, 86, 92, and 133 of Barnard's catalogue, as well as No. 33 near ζ Orionis, afford striking evidence of the obscuration of stars by intervening masses. It is hoped that the photographs of these objects may be of future use for detecting motion in the obscuring masses or in the stars near their edges by the disappearance or emergence of some of the stars.

(6) N. G. C. 6822. This appears to be a remarkable group of stars and small nebulæ, with probably some diffuse nebulosity. Two of the small nebulæ resemble comets with bifurcated tails. The longer of two exposures was made under poor conditions and the images are not good. A still longer exposure, with good seeing, is needed.

From a study of the above photographs, Mr. Duncan has obtained the following results:

1. Three novæ, Nos. 18, 19, and 20, were discovered in the Andromeda nebula.

2. Two new variable stars were discovered in the Trifid nebula.

3. A variable star in M 33, discovered in the summer of 1920, was found to be redder than its neighbors and probably of long period.

4. Two stars of noticeable proper motion were discovered in the globular cluster M 15.

5. Lampland's discovery of changes in the Crab nebula (M 1) was confirmed by comparison of a plate made with the 60-inch telescope by Ritchey in 1910 with one made by Duncan in 1921; the motions of 12 nebulous condensations with respect to 13 comparison stars were measured. The displacement of the nebulous points was in general away from the center of the nebula. The maximum displacement in the $11\frac{1}{2}$ years interval was about 2″.5.

6. The evidence afforded by comparing the photographs of M 99 with two plates taken by Mr. Seares in 1916 is insufficient either to confirm or disprove the changes announced by Lampland.

MISCELLANEOUS PHOTOGRAPHS.

A few photographs of the moon, Jupiter, Saturn, and Venus have been made by Mr. Pease with the 100-inch telescope.

Photographic observations of the positions of the Eighth and Ninth Satellites of Jupiter were made by Mr. Nicholson with the 60-inch telescope. No ephemeris for either satellite was available. Approximate positions were computed and the satellites searched for until found.

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS.

During the year Mr. van Maanen has secured 370 plates at the 80-foot focus of the 60-inch reflector with 614 exposures. Of these, 455 exposures were for the determination of parallaxes, 139 for proper motions, and 20 for photometric determinations. For 22 fields the necessary plates were secured for the determination of parallaxes, thus giving a total of 144 fields finished to date. Several of the results require comment.

a. Parallaxes were derived for 5 long-period variables: T Cassiopeiæ, R Trianguli, R Virginis, R Canum Venaticorum, and X Ophiuchi. Including, also, the parallax of *o* Ceti determined by other observers, mean absolute magnitudes for these objects were found to be as follows: maximum about +1.5; minimum +6.5; at maximum these stars are therefore giants. Any theory of their variability must keep this fact in view.

b. For two Cepheids, RX Aurigæ and RR Lyræ, the parallaxes found are −0″.001 and +0″.006, respectively, thus confirming previous determinations of the absolute brightness of stars of this type.

c. The parallax found for R Monocerotis (N. G. C. 2261), the well-known variable nebula, is negative. The true parallax must therefore be very small, probably less than +0″.005. To explain the extraordinary changes in the nebula observed by Mr. Hubble, it seems necessary to conclude that the necessary motions are an effect of illumination and do not represent a real motion of nebulous matter.

d. A parallax of +0".10 was derived for the faint star of magnitude 13.2, proper motion 0".38, discovered by Mr. van Maanen while measuring the parallax of Boss 1182. This indicates an absolute magnitude of +8.2 and a velocity at right angles to the line of sight of about 180 km. per sec.

A series of parallax plates has been started at the 42-foot focus of the 100-inch reflector; the program includes objects which are too faint or too far south to be dealt with at the 80-foot focus of the 60-inch telescope. Among these are some of the largest planetary nebulæ, a few early novæ, and some faint stars of large proper motion.

Two pairs of plates of 5-years' interval, of the region around α Tauri, have been measured for proper motion. Of 65 stars down to magnitude 15, not one appears to be a member of the Taurus group; the percentage of faint stars belonging to the cluster must therefore be extremely small.

Mrs. Marsh has assisted in the computations relating to parallax and proper motion and has also measured ten fields for the determination of proper motions of stars of about the twelfth magnitude. For this purpose several plates originally taken for the determination of parallax were duplicated, the interval being five or six years.

STELLAR PHOTOMETRY.

Several hundred photographs have been made for photometric purposes with the 10-inch refractor and the reflectors by Messrs. Seares, Shapley, Hubble, Humason, and Lindblad of a variety of objects. Besides the determination of photographic and photovisual magnitudes in the special fields referred to below, a series of 66 photographs of the cluster M 5 has been made, at the request of Professor Turner, by Mr. Seares and Mr. Lindblad, for the determination of the magnitudes of comparison star k of Bailey's variable No. 33. Star k is a variable of short period and small amplitude.

An object of unusual interest, called to our attention by Professor von Zeipel, is a very red star of about the thirteenth photovisual magnitude in the edge of the cluster M 37. The star is a variable of unknown period and amplitude. Its color-index seems to be of the order of five magnitudes. Polar comparisons have been made for the determination of its brightness and color, but the photographs have not yet been reduced.

Mr. Hubble has used the 10-inch Cooke refractor to determine by polar comparisons the photovisual magnitudes of 250 stars involved in or neighboring on nebulæ and nebulous clusters. Photographic magnitudes have been determined for 160 of these stars. Ordinary photographic magnitudes obtained with this instrument are much less precise than photovisual. The color curve of the lens is so steep that, when focused for $H\gamma$ (best focus for faintest images), the ultraviolet light is out of focus and produces diffuse images for all but the faintest stars. A potassium-chromate filter, prepared by Mr. Anderson, finally solved the difficulty by cutting off the light above λ4150. Sharp images are now obtained, entirely comparable with those given by a visual color filter, over a range of at least five magnitudes. The color equation for photographic magnitudes is considerably increased, but this is more than offset by the greater accuracy with which the images can be measured. Another advantage of the filter is that, when used with a Seed process plate, bright-line nebulosity is much reduced in intensity, and involved stars can be measured undisturbed by a nebulous background. Thus the trapezium stars in Orion give well-separated images, free from nebulosity and easily measurable, in spite of the short focus of 45 inches and the large focal ratio F 4.5.

The systematic observation of colors by Mr. Seares has centered mainly on nebulous stars, galactic clouds, and special fields in some of the obscured regions of the sky for the purpose of obtaining evidence bearing on certain investigations undertaken by him jointly with Mr. Hubble. The program of nebulous stars, with a few exceptions, is complete. The results are described on page 255. The galactic clouds and obscured areas are discussed below.

A series of the color comparisons of the Selected Areas in the +30° zone with the North Pole is half finished. The results will serve a threefold purpose: provide secondary standards of color, useful for the determination of the plate constants for exposure-ratio photographs of fields south of the zenith, permit a study of color as a function of galactic latitude, and afford a valuable control on the zero-point determinations of the photographic and photovisual scales established for the Selected Areas. Much work has also been done on a standardization of the relations between exposure ratio, color-index, and spectral type.

Most observations hitherto made by the method of exposure ratios have been of individual and rather bright stars. For such objects it is easy to arrange the observations so that gradation differences in the photographic plate for blue and yellow light are eliminated. When bright and faint stars are observed simultaneously, however, the problem is much more difficult. The matter has been given much attention, and results seem to justify the belief that the method of observing and reduction now used is free from this objection.

Mr. Humason has made photographs of M 22 in a search for variable stars, and of the Andromeda nebula for the detection of possible novæ. He has also taken about 100 plates of special fields, many of which have been compared with the pole.

Photographic and Photovisual Magnitudes in the Selected Areas.

The combination of results obtained by Professors Kapteyn and van Rhijn with those derived by Mr. Seares with the assistance of Miss Joyner and Miss Richmond has continued. Some 25,000 or 30,000 stars measured at Mount Wilson fall outside the limits of the Groningen measures. These are in process of transfer to cards for arrangement in catalogue form. The results, including the checking of the coördinates, are practically complete for Areas 1 to 67.

The observing program for photovisual magnitudes in 42 of the Selected Areas has been finished. With the exception of a small number of plates, the measures are complete; the reductions are well advanced, although little has been done during the year because of concentration of effort in other directions.

Photometric Survey of the Pleiades.

With the assistance of Miss Richmond, Mr. Shapley has finished a survey of the photographic and photovisual magnitudes of about 850 faint stars in the Pleiades, many of which are certainly members of the physical system. The magnitudes were determined by comparison with the North Polar Standards, and will be of importance for statistical discussions and for comparisons of the Mount Wilson photometric system with that of other observers. The interval covered is from magnitude 10 to 15.5. Within this interval the members of the cluster are dwarfs, of absolute magnitudes 5 to 10.5. Beyond the eleventh magnitude the mean color index of cluster and background stars is sensibly constant and equal to about 0.7 mag.

North Polar Standards of Magnitude.

In connection with the work of the International Committee on Magnitudes, of which Mr. Seares is chairman, several tests of the Mount Wilson photometric scale have been undertaken. These concern mainly the relation of the standards below the tenth magnitude to those near the sixth magnitude, which define the international zero-point. To obtain evidence involving the use of an instrument other than the 60-inch reflector, with which the standards were established, Mr. Humason has begun a series of observations with the 10-inch refractor.

A second test is based on a comparison of the results described in the preceding paragraph with a long series of photographic magnitudes and color-indices of stars in the Pleiades, placed at our disposal by Professor Hertzsprung. The scale for the latter series was established by means of an objective grating attached to the 80-cm. refractor of the Potsdam Observatory and is referred to the zero-point of the Göttingen Aktinometrie. The color indices depend on measures of effective wave-length on photographs taken some years ago by

Professor Hertzsprung with the 60-inch reflector. The relation of the zero-point of the Aktinometrie to that of the Mount Wilson system and the color equation of the instrument are known. A comparison can therefore be made with the Mount Wilson system as transferred to the Pleiades by Mr. Shapley's observations. For the well-determined interval of the scale the differences, in hundredths of a magnitude, are in the accompanying table.

The mean difference for the photographic magnitudes is +0.02 mag.

Photographic magnitude.	Mt. Wilson–Hertzsprung.			Average No. stars.
	Photogr.	Photov.	C. I.	
11.5–12.0......	+12	+ 2	+10	32
12.0–12.5......	+ 6	+ 3	+ 3	42
12.5–13.0......	− 2	− 5	+ 5	59
13.0–13.5......	+ 3	− 3	+ 5	72
13.5–14.0......	+ 3	− 6	+ 6	135
14.0–14.5......	−10	−13	+ 2	112
Mean.......	+ 2	− 4	+ 5	....

The correction for zero-point difference is −0.06, and for reduction of Hertzsprung's results to the color system of the reflector, +0.04. Hence, the final difference for the photographic scale is 0.00 mag. In other words, Professor Hertzsprung's measurement of the interval between the sixth and thirteenth magnitudes is the same as that made at Mount Wilson. The small systematic difference of 0.05 mag. in the color-indices is within the uncertainty of the determination. The same difference reappears in the photovisual magnitudes with the reversed sign, since Hertzsprung's results for these were obtained by combining his photographic magnitudes and color-indices.

A third test, which concerns the Mount Wilson color-indices, is an amplification of one described in Proceedings of the National Academy of Sciences, vol. 3, 29, 1917. The method of determining colors by exposure ratios, which is entirely independent of scales of magnitudes, was calibrated on the bright stars among the Polar Standards and then used to determine the color indices of the standards fainter than the tenth magnitude. A comparison of these results with the values of the color derived from the photographic and photovisual magnitudes gave no evidence of any systematic difference as far as magnitude 15.5. The comparison has now been greatly strengthened and extended to a little below the sixteenth magnitude, with results that are equally accordant.

Color of the Brighter Stars in the Pleiades.

Mr. Seares has reduced a series of 15 exposure-ratio photographs of the Pleiades for the determination of the colors of the bright stars and of some of the fainter objects as far as the twelfth magnitude, mainly as a test of the method of reduction. Color-indices were obtained for 60 stars. The agreement with Professor Hertzsprung's results referred to above is excellent, only two of the differences for individual stars exceeding a tenth of a magnitude. The mean systematic difference ranges from −0.02 mag. for the brightest stars to +0.02 mag. for those near the twelfth magnitude. This close agreement over an interval of 8 magnitudes is good evidence that the disturbing influence of gradation has been well eliminated.

The measures confirm two anomalous results which had been suspected from other evidence. The color-indices of the 14 A0 stars which are members of the cluster increase with increasing magnitude, the change amounting to about 0.2 mag. in an interval of two magnitudes. Further, the color-indices of the F and G stars are about one-third the values usually found for these types. For the A stars, at least, the result is probably to be attributed to systematic errors in the spectral classification.

Galactic Clouds and Obscured Regions.

The colors of stars in rich galactic fields in Perseus and Taurus have been compared with those in several closely adjacent areas within and on the boundaries of regions showing great obscuration. In addition, measures of color have been made in a number of Selected Areas, especially Nos. 63, 64, 88, 109, 110, 111, and in several rich fields in the Scorpius-Sagittarius region. Area 110 is on the equator, between the two branches of the Milky Way, and is notable because of the low-star density, which is comparable with that in high galactic latitudes. As far as the reductions are complete, they indicate the following results:

The galactic fields show a correlation of color with apparent magnitude which is the inverse of that previously found for extra-galactic regions, but similar to that occurring among the most luminous stars in globular clusters and the Cepheids and pseudo-Cepheids of our own system. On the average, the stars in the galactic clouds become bluer with increasing magnitude. There are exceptions, as might be expected, for although there is reason to believe that the correlation exists among the more luminous stars in a galactic aggregation which are at the same distance from the observer, there are two factors which tend to prevent its detection: the presence of any considerable number of apparently bright blue stars, and, second, exceptional thickness of the cloud in the line of sight. These will decrease the average color of the apparently brighter stars and increase that of the fainter objects. The very distant red giants, say of absolute magnitude −4, in the remote regions of the cloud, will have the same apparent magnitude as nearer and intrinsically fainter blue stars. The result will be the presence of stars of all colors in every interval of apparent magnitude, and an average color that changes little with decreasing brightness. The nearby dwarfs, which are all reddish, can have little influence because of their small number.

The immediate importance of the phenomenon lies in its applicability to a determination of the distances of the cloud-forms of the Milky Way. When the correlation is clearly defined, the method should give excellent results, for the relation between mean color and luminosity is well established by the spectroscopic parallaxes of the Cepheids and pseudo-Cepheids, and especially by the extensive determination of colors and absolute magnitudes in globular clusters by Mr. Shapley. Even when the relation is more or less completely obscured, valuable indications of distance—minimum distances, at least—should be possible. A survey of the evidence bearing on correlations of luminosity with spectral type and color (p. 275) indicates that the blue stars in the galactic clouds are approximately of zero absolute magnitude. The adoption of this value gives at once an approximation for the distance, which can only be increased by the assumption that the clouds, like the loose aggregations of B stars in our own system, also contain blue stars of much higher luminosity.

Very provisional results for four regions are:

Selected Area 88	14000 parsecs.
Scutum Sobieski	7000
$4^h\ 2^m$ +33° 15′ Perseus	8000
4 16 +26 3 Taurus	7000

At a minimum, therefore, the distances of the blue stars in these fields, of apparent magnitudes 14 to 15.5, seem to be of the order of 20,000 to 50,000 light-years.

The obscured areas for which results are complete are in Perseus and Taurus. The stars are predominantly red, but thus far no evidence of an excess of color over that to be inferred from spectral type has been found which can certainly be attributed to the obscuring material. Mr. Hubble has made long exposures of the regions in question with objective prisms on the 10-inch refractor. As far as the spectral classification can be pushed, it indicates an abnormally high percentage of late types, many of which, according to Mr. Lindblad, are certainly dwarfs, agreeing closely with the colors measured by exposure ratios and checked by polar comparisons. The inference is that the obscuring material is comparatively near and obstructs, without perceptible scattering, the light of the more distant stars. On this hypothesis, the stars seen within the boundaries of these areas would lie between the observer and the obscuring cloud and include a large percentage of dwarfs, which in the nature of the case are of high color. Thus in one of the fields in Taurus, at $4^h\ 15^m$, +28° 10′, the types of 7 well-determined stars within the boundaries of obscuration ($m=8.5$ to 12.2) are all G or later; 6 of the 7 stars are dwarfs. The brightest is a K0 giant. The measures show a small color excess, less in amount, however, than the uncertainty affecting it. Assigning to the dwarfs mean absolute magnitudes corresponding to their types, we have 5.5

for the mean value of $m-M$, with an average deviation of ±0.3 mag. for individual stars. The corresponding mean parallax is 0″.008. The obscuring material can scarcely be nearer, and probably is not more than three or four times the distance indicated by this value.

A possible exception to the statement that stars in obscured areas do not show much, if any, excess of color occurs among the faint stars near *o* Persei, which are in a region of marked obscuration. The details are discussed in connection with nebulous stars on page 255. Here it need only be remarked that the certain instances of excess color thus far found anywhere are those of stars surrounded by luminous nebulosity. Although *o* Persei is in an obscured region, it is near the nebula I. C. 1985, which involves nearly all, if not all, of the objects showing an excess of color.

Star Clusters and the Galactic System.

The investigation of the star clusters and their bearing on the structure of the Galaxy has been continued by Mr. Shapley as in the past, a large number of plates having been made with the reflecting telescopes for both photometric and spectroscopic studies. Slitless spectrograms of globular clusters have confirmed the earlier conclusion that the brightest stars are giants.

The distribution of stars and the character of the variables in the condensed type of globular cluster have been examined in order to determine the distances more accurately and to find in what important respect these few objects differ from typical globular systems. An examination of many thousands of the fainter stars in the brightest globular clusters has been made by Miss Mayberry without finding any conspicuous cases of variation.

The distance of N. G. C. 7006 has again been determined, this time by means of its newly discovered variable stars; the earlier value of 220,000 light-years is confirmed, with much higher weight than was possible before. The dimensions of this most distant cluster and of the relatively near cluster M 13 are essentially the same.

The distribution of the stars with respect to the plane of the local cluster and the galactic plane has been further investigated with the aid of the data contained in the unpublished volumes of the Henry Draper Catalogue. The brighter stars of spectral type B show clearly the phenomenon of a secondary Milky Way; the fainter B stars, however, show a symmetrical distribution with respect to the plane of the Galaxy and evidently are not members of the star-cloud immediately surrounding the sun.

Variable Stars.

A contribution to the problem of the velocity of light is made by Mr. Shapley's comparative study in blue and yellow light of the variable stars in M 5; the investigation is still in progress. The close coincidence of the maxima of the cluster-type variables for different colors shows that the velocity of light in space is the same for blue and yellow light within one part in a billion. That is, the radiation, which differs in wave-length by approximately a thousand angstroms, differs in velocity by less than one foot a second.

From a study of the light curves of Novæ and variable stars, Mr. Shapley has established with some certainty the existence of a continuous gradation from the so-called typical Nova light-curve, such as that of Nova Aquilæ No. 3, to the curves for a certain type of irregular variable star of small variation, similar to those in the Orion Nebula. Spectroscopic results, so far as they go, confirm the relation of the two types, and it is suggested that the cause of variation of Novæ and of these variable stars differs in degree rather than in character. Unpublished photometric and spectroscopic results from the Harvard College Observatory were of much value in this study.

The close relationship of the spectra and light curves of Novæ and certain variable stars like T Pyxidis has been noted by previous observers.

Mr. Shapley has examined the question of changes in geological climates from the standpoint of recent observations on the movement of stars in nebulosity. The peculiar and difficult variables in the Orion Nebula apparently owe their light variations to friction with the surrounding nebulosity, and the prevalence of similar nebulosity throughout the solar neighborhood raises the question of its possible effect in the past on solar radiation and terrestrial temperatures.

The computational work on eclipsing binaries has been continued by Mrs. Shapley. One of the variables studied, SX Cassiopeiæ, is of special interest because its mean density is of the order of 0.0005 of the solar density. The variable is, in fact, a very close pair of giant stars, each with a linear diameter comparable with that measured for Arcturus with the interferometer.

Mr. Shapley and Miss Mayberry have completed an investigation of the 19th magnitude variables of the globular cluster N. G. C. 7006—the faintest and most distant variable stars on record. Seven of the eleven found on the Mount Wilson plates show conspicuous variation in the course of one night, and the other four appear also to be short-period variables. In magnitude and range they are very much alike; and in this cluster, as in M 3, M 5, and other systems, the variables are between one and two magnitudes fainter than the brightest stars. They are, no doubt, typical short-period Cepheids.

Preliminary Experiments on Stellar Photometry in the Infra-Red.

Last summer experiments were begun to determine the possibilities of the new thalofide cells for the measurement of stellar radiation. These cells behave similarly to selenium upon exposure to light, except that their spectral sensitivity lies between 6,000 A and 12,000 A, with a maximum at 10,000 A. It was found that cell No. 7 underwent a

5 per cent change of resistance upon exposure to the light of Arcturus at the focus of the 60-inch telescope. The high resistance of the cell (300 megohms) made it unsatisfactory, however, for use in series with a galvanometer directly. It was therefore decided to attempt the use of a thermionic vacuum tube for amplifying the galvanometer deflections. After some difficulty an electrostatic audion voltmeter was perfected which was capable of measuring voltages as low as 10^{-4} volts. The method of operation then consisted in connecting the thalofide cell in series with a battery and a resistance the value of which was the same as that of the cell. Changes in the resistance of the cell due to exposure to light caused changes in the potential across the series resistance. These potential variations were then measured with the thermionic voltmeter. The first test of the device with the 60-inch reflector gave the following results:

Star.	Spectrum.	Magnitude (visual).	Galvanometer deflection in mm.
β Pegasi	Ma	2.2–2.7	52.0
φ Pegasi	Ma	5.2	4.0
α Andromedæ	A0p	2.2	5.0

Experiments are being carried on with a cell of smaller surface area, with which it is hoped to reach much fainter stars.

STELLAR SPECTROSCOPY.

The stellar spectroscopic work of the year has been carried on by a considerable number of observers, and their investigations have dealt with a wide variety of problems. The following summary indicates the principal divisions of the work:

General program of radial velocities and determinations of absolute magnitude: Adams, Joy, Strömberg, Hoge.
Variables of type Md and stars with bright lines: Merrill, Humason.
Spectroscopic binaries and R-type stars: Sanford, Duncan.
Nebulous stars: Hubble.
Investigations of absolute magnitude for B and A stars: Lindblad.

The two slit spectrographs have been in regular use at the Cassegrain focus of the large reflectors, and a small spectrograph of short focal length has been employed occasionally at the primary focus, both with and without a slit. In addition, a considerable number of photographs have been obtained by Mr. Hubble, Mr. Humason, and Mr. Lindblad with the 10-inch refractor and an objective prism. Most of the spectrograms taken at the Cassegrain focus have been made with a dispersion of one prism and a camera of 45 cm. focal length. The 18-cm. camera has proved most valuable, however, in the case of the fainter variables which have been investigated.

During the year, 1,549 spectrograms have been obtained with the Cassegrain spectrographs, 634 with the 100-inch telescope, and 915 with the 60-inch. The 100-inch telescope has been used almost exclusively for faint stars and for a few selected objects south of −30° declination which are beyond the reach of the 60-inch reflector. The observing list for the latter instrument consists to a large extent of stars for which determinations of absolute magnitude are being made and includes stars with a wide range in apparent brightness.

The following table shows the number of stars of the various magnitudes observed with the two reflectors at the Cassegrain focus:

	100-inch.	60-inch.
Brighter than 5.0 visually	43	99
5.0 to 5.9	31	267
6.0 to 6.9	39	324
7.0 to 7.9	142	170
8.0 to 8.9	207	50
9.0 or fainter	172	5

Radial Velocities.

The principal results obtained during the year are as follows:

(1) The radial velocities of 253 stars in addition to those of types Md and R have been determined from three or more spectrograms, and these stars have been transferred to the list of objects with constant velocities.

(2) About 20 spectroscopic binaries have been discovered, for several of which the orbits are now under investigation.

(3) The elements of the orbits of 7 spectroscopic binaries have been computed and published by Mr. Sanford. These include the companion of α Herculis with a period of 51.6 days, and two dwarf stars of type K, Lalande 29330 and Lalande 46867, the latter of which has bright H and K lines. Preliminary elements of three other binaries, Boss 2227, Boss 2447, and A. Oe 12584, have been derived. Four of these ten binaries show the lines of both components. The large velocities of the center of mass of Lalande 29330 and A. Oe 12584 are noteworthy, amounting to −60 and −98 ± km. per sec. respectively

(4) The Cepheid variable X Cygni has been investigated by Mr. Duncan, and the elements of its orbit have been determined on the assumption that this type of variable is actually binary in character.

(5) The variable star S Antliæ, usually classed as a Cepheid variable, has proved to be of the Algol type and shows two spectra. The orbit has been calculated by Mr. Joy, and the results will be published soon.

(6) Observations of the cluster-type variables RS Boötis, XZ Cygni, and RV Ursæ Majoris indicate a somewhat larger range of velocity for these stars than for the normal Cepheid variables. The "velocity of the system" in the case of ten cluster-type variables has been found to have values ranging from +70 to −180 km. but no relationship with distance from the Galaxy is apparent.

(7) Marked differences are shown in the radial velocities given by the dark and bright lines of the Cepheid variable W Virginis.

(8) Radial velocities have now been determined by Mr. Merrill for 101 long-period variables. Of these, 91 have spectra similar to that of *o* Ceti, while the remaining 10 are classed as peculiar.

(9) A least-squares solution by Mr. Merrill for the solar motion from the bright lines of 83 variables of the Md (*o* Ceti) type yields the values V = −56 km., A = 274°, D = +44°. The average residual radial velocity is 31 km., the greatest motion so far observed for a group of stars selected on the basis of spectral type. The high value of the solar motion is in agreement with the result found from statistical investigations by Adams, Joy, and Strömberg, that stars of high velocity have a strong preferential motion in a direction nearly opposite to that of the sun.

(10) The radial velocities of 28 stars of type R have now been determined by Mr. Sanford. The velocities show the extraordinarily high dispersion of from −400 to +70 km. The algebraic mean when freed from the effect of the solar motion is −17 km. and the numerical mean is 50 km.

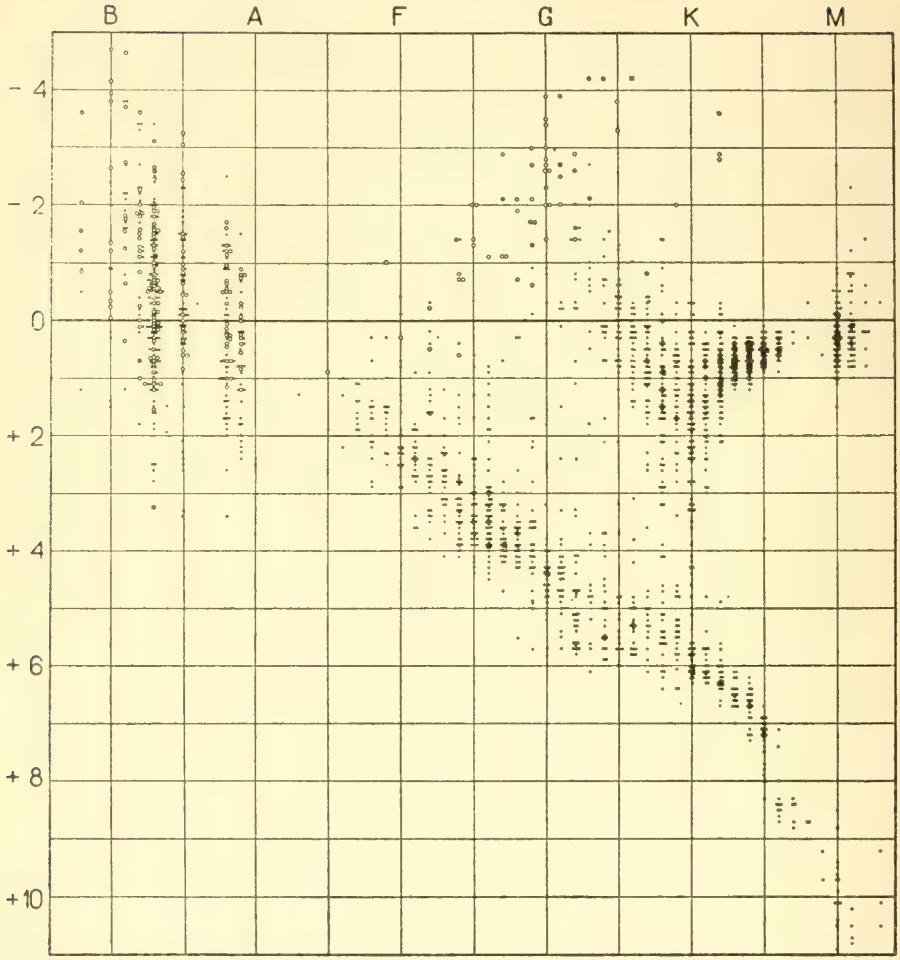
SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX.

The absolute magnitudes and parallaxes of 1,646 stars derived by the spectroscopic method are contained in Contribution No. 199, published by the Observatory in January 1921. The contents of this paper may be summarized as follows:

1. Derivation of the reduction tables with the aid of trigonometric parallaxes, parallactic motion, and peculiar motion.
2. Illustrations of the use of the reduction tables.
3. Derivation of the probable errors. These are found to be of the order of ±0.4 in the absolute magnitude and about 20 per cent in the parallaxes themselves.
4. Comparisons with trigonometric parallaxes and with spectroscopic parallaxes derived previously.
5. Methods employed in the determination of the relative intensities of the lines used for the various types of spectra.
6. Catalogue of the results for 1,646 stars.

The spectroscopic method of determining absolute magnitude has now been applied to about 350 stars in addition to those for which results have been published, so that a total of 2,000 parallaxes derived in this way is now available.

One of the most direct applications of these results is to the giant and dwarf theory of stellar development. If the stars are divided according to spectral type and the numbers of stars of each absolute magnitude are counted it is found at once that the A and F type stars (excluding the Cepheids and pseudo-Cepheids) show a single maximum of frequency, the former around absolute magnitude +2, the latter around +3.5. The G and K0 to K 3 stars show two maxima, the first at +0.5 and +5.5, the second at +0.5 and +6.2, with com-



Distribution of about 2,100 stars with respect to spectral type (abscissæ) and absolute magnitude (ordinates). The points and circles represent individual stars. The B stars are those in the Orion (circles) and the Scorpius-Centaurus (points) regions investigated by Kapteyn. The remainder are stars whose absolute magnitudes have been derived spectroscopically by Adams and his associates. For types A to M the circles indicate Cepheid variables and pseudo Cepheids.

paratively few stars of intermediate magnitude in either case; and, finally, the K4 to K9 and M stars show two maxima completely isolated from each other, the first type at +0.7 and +7.0 and the second at +0.2 and about +10.5. The separation of the two branches of the curve of development is shown clearly by these results.

A graphical representation of the results for the 1,646 stars and for the helium stars whose parallaxes were determined by Professor Kapteyn is given in the accompanying diagram prepared by Mr. Hubble. The absolute magnitudes are plotted against spectral types, the Cepheids and the stars of the Orion group among the helium stars being indicated by circles. The nature of the giant and dwarf division is shown clearly, as well as the marked grouping of the stars with the Cepheid characteristics of spectrum. The extraordinary condensation of stars around K1 to K5 is due in part to the Harvard system of classification, which requires modification to include spectral types between K5 and Ma.

An investigation by Mr. Lindblad of the influence of the effect of absolute magnitude on the spectrum of stars of types B and A has led to the discovery that the portion of the continuous spectrum between λ3895 and λ3907, when compared with the adjoining region toward longer wave-lengths, is less intense in stars of low luminosity than in the brighter stars. The effect appears to be due to a widening of the wings of $H\zeta$ in the fainter stars and to increased width and intensity of the arc lines of iron and the silicon line at λ3906. The method of comparison is to determine the exposure-ratio necessary to secure equal photographic impressions for the two spectral regions λ3895–λ3907 and λ3907–λ3925. Between absolute magnitudes 0 and +3 the rate of change in exposure ratio is found to be 0.15 mag. for one unit in absolute magnitude, with a probable error of about 0.10 mag. for a single plate having from 3 to 8 measured images. The effect appears to be most prominent in stars of types B8 to A5, and to become less for stars with types on either side in the spectral sequence.

The principal applications of the method have been to stars in moving clusters such as the Ursa Major group, the Hyades, Pleiades, and Præsepe, and to the B-type stars of the Orion and Scorpius-Centaurus groups. In all these cases the parallaxes as determined by this spectroscopic method are in good agreement with those derived from group motion or by other means.

Mr. Lindblad has also investigated the cause of the sharp falling off in intensity of the continuous spectrum beyond λ3889, which from his own work at Upsala and that of Kapteyn is known to be correlated with absolute magnitude. The effect is found to be due to increased absorption of the "cyanogen" band λ3883 in the more luminous stars. The same result, but in less degree, exists for the bands at λ4216 and λ3950. The most sensitive point in the band at λ3883 appears to lie between the two heads at λ3883 and λ3871, where the effect seems to be marked even among the giant stars of the same spectral type.

The exposure-ratio method already referred to has been used for measuring the amount of the change of intensity between the two regions to be compared, as, for example, λ4144–λ4184 and λ4227–λ4272. The amount of the effect appears to be greatest for stars of types G5–K2 and decreases considerably toward G0 and Ma. Slitless spectrograms of stars as faint as apparent magnitude 13.5 indicate that the method can be applied with success to distinguish between giant and dwarf stars of this brightness.

Space-Velocity and Absolute Magnitude.

The determination of the distances and absolute magnitudes of stars has made it possible, through combination with proper motion and radial velocity, to derive space-motions and to study their relationship to absolute magnitude. An investigation of this character, based upon the results for the 1,646 stars to which reference has been made, leads to results of considerable interest.

1. The average space-velocities of stars of types F, G, K, and M vary with absolute magnitude to a marked degree, the fainter stars moving more rapidly than the brighter ones. The giant stars show an especially regular increase of velocity with decreasing brightness. The increase in average space-velocity is about 3 km. for a decrease in brightness of one magnitude.
2. The tangential and radial velocities show results in harmony with the space-velocities.
3. The average space-velocity of the giant stars is very nearly twice the average radial velocity, a result which would follow strictly if equal numbers of stars moved in all directions.
4. The variation of velocity with spectral type is well marked among the giant stars, but less certain among the dwarfs. The latter show a very wide dispersion of motions and are much less homogeneous as a class than the giants.
5. The frequency of the space-velocities can not be represented by a distribution according to Maxwell's law, there being a large excess of high velocities. The assumption of a normal error-distribution of the logarithms of the velocities instead of the velocities themselves satisfies the observations much better.

Systematic Motions of Stars Based upon Space-Velocities.

An extensive investigation by Mr. Strömberg of the systematic motions of stars with parallaxes derived by the spectroscopic method is now in progress. Brief reference may be made to a few of the results.

1. Solutions of the solar motions based separately upon 800 giant stars and 415 dwarf stars give values for the velocity for the sun of 19.1 km. and 32.4 km., respectively. The difference is found to be due to systematic motions on the part of the dwarf stars.
2. A similar solution, using groups of stars divided according to the amount of space-velocity, shows that the stars with space-velocities between 0 and 60 km. yield a value of the solar motion in close agreement with that commonly adopted, $V=20$ km., with the apex at $A=270°$, $D=+30°$. The stars with higher velocities give systematically larger values for A and D and a great increase in the apparent value of V.
3. The conclusion from these results is that the motions of the stars with large velocities, the great majority of which are of the F type and

of the dwarf class, are not distributed in the same way as the stars of normal speed, but show a very asymmetrical distribution, their centroid moving towards a point in the galaxy of galactic longitude about 250°. The same result was found previously by Adams and Joy from a smaller number of stars of large radial velocity.

Spectra of Nebulous Stars.

The investigation of the spectra of stars involved in nebulosity has been carried on by Mr. Hubble with the aid of the Cassegrain spectrographs and a small slitless instrument which may be used at the primary focus of either of the telescopes. With the latter instrument the spectra of about 150 stars ranging in magnitude from 10.5 to 14.0 have been classified.

The spectra of 85 stars have been photographed with the Cassegrain spectrographs. The stars involved in extended nebulæ giving an emission spectrum are nearly all of types Oe5 and B0. Those in extended nebulæ giving an absorption spectrum are B1 or later, averaging about B4. The following six stars of types later than A3 are found to be involved in nebulosity:

B. D. +31° 597	K2 giant
$4^h\ 14^m$, +28° 5′ (1920)	K8 dwarf
T Tauri	Gp with bright lines
B. D. +28° 645	F8
B. D. −19° 4357	G5 giant
R Coronæ Australis	Gp with bright lines

The central stars of all the large planetary nebulæ so far observed, N. G. C. 246, 1514, 3587, 6853, 7293, and 7635, with mean diameters exceeding 2′, have spectra intermediate between the Wolf-Rayet type and Oe5.

The bearing of these results on the nature of the spectra of the nebulæ with which the stars are connected is discussed in another section of this report (p. 254).

Miscellaneous Investigations.

1. Observations of ο Ceti were continued as far as its minimum of light, and show a repetition of the remarkable changes in its spectrum which were first seen at the preceding minimum. A curious longitudinal asymmetry in the bright hydrogen lines and the bright regions adjoining the heads of the titanium-oxide bands was observed. The components of the hydrogen lines were displaced with reference to each other by an amount which would correspond to an angular distance of 0″.2 in the sources producing the lines.

2. The spectrum of R Scuti was observed on April 17 to have strong M-type bands which disappeared by May 24. The spectrum was estimated as G5 on June 11. Strong, sharp enhanced lines are very prominent in the spectrum. No bright lines were found.

3. The following variables of long period belonging to the Algol and Cepheid classes have been found to have bright lines. In most cases the strength and appearance of bright lines vary with the light variation. The spectra of all of these stars show Cepheid characteristics strongly, and there seems to be no means of determining the type of variation from their spectra. Only one component is visible, but all except RT Serpentis and RZ Ophiuchi show a considerable range in velocity:

	Mag.	Period.	Spec.	Class.
RT Serpentis.....	9.6–15	Several years.	A8p	?
RZ Ophiuchi.....	9.7–10.5	262 days	G0p	Algol
TT Ophiuchi.....	8.9–11.0	61 days	G0p	Algol
SX Cassiopeiæ...	8.7– 9.7	36 days	A6p	Algol
RX Cassiopeiæ ..	8.7– 9.4	32 days	G2p	Algol
RU Camelop	8.5– 9.8	22 days	R	Cepheid
W Virginis.......	8.7–10.4	17 days	G0p	Cepheid
W Serpentis.....	8.5– 9.6	14 days	F9p	Cepheid

4. The spectrum of Nova Aquilæ 1918 and its surrounding ring has changed but slightly in the last year. The ring has decreased in brightness relatively to the central star, but the same twisted features remain in the nebular bands, N_1 and N_2. The bright extremities or "knobs" of these bands and the band at λ4686 are the only breaks in the strong continuous spectrum of the nucleus.

5. The spectrum of Nova Cygni 1920 was observed from August 22 to September 4, 1920. The early plates showed a spectrum similar to that of α Cygni. Bright bands were prominent on August 25. Two absorption components of the hydrogen lines were measured on September 4. The displacement of the absorption lines other than hydrogen increased from −6 A on August 22 to −14 A on August 27. The velocity of the star as determined from the sharp H and K lines is −18 km.

6. The spectrum of T Coronæ, the Nova of 1866, is found to be of type M with a very strong bright $H\beta$ and a less pronounced bright $H\gamma$. A bright line at λ4686 is a marked feature of the spectrum. The absorption lines agree closely in character and intensity with those of a typical giant star of type Ma.

7. A few slitless spectrograms of Novæ have been obtained by Mr. Pease at the primary and Cassegrain foci of the 60-inch and 100-inch reflectors. Those of Nova Aquilæ 1918 show images of the ring in light from the $H\alpha$ and N_1 and N_2 lines.

8. Fürujhelm's distant companion to Capella was found to be an Ma dwarf star with the same parallax and radial velocity as Capella itself. The close companion of Antares is of spectral type B3 with wide hazy lines. An excellent photograph of the spectrum of the faint com-

panion of Sirius, secured with the 100-inch telescope, confirms in general the previous results obtained some years ago with the 60-inch reflector. The spectral type is somewhat more advanced than that of Sirius, but can hardly be later than F. The line λ4481 appears to be abnormally weak.

9. A continuation of the study of the spectrum of R Aquarii by Mr. Merrill shows the presence of several nebular lines in addition to N_1, N_2, and λ4363 superposed upon a spectrum of type Md. The displacement lines of the nebular spectrum seem to be the same (within the limits of error of measurement), with the exception of λ4363, which, relatively to the others, appears to be displaced about 0 2 A to the violet.

10. A study has been made by Mr. Merrill of the behavior of the more prominent bright lines of certain Md stars and their relative intensities at different phases of light. The same lines are found to be present after maximum in the spectrum of the long-period variable R Cygni, a star with a very different type of absorption spectrum from that of the Md variables.

11. Mr. Humason and Mr. Merrill have discovered during the year, on photographs taken with the 10-inch refractor and objective prism, more than 50 stars with the $H\alpha$ line bright. This makes a total of about 65 such stars found at Mount Wilson. Several of these stars show spectra of the P Cygni type, the structure being qualitatively similar to that of Novæ.

Peculiar Class A Stars.

The stars of class A, noted by Miss Cannon as having peculiar spectra, in which the silicon lines λ4128 and λ4131 are strong, have a mean absolute magnitude of about −0.2 and are decidedly brighter than the general run of A stars. Those in whose spectra the strontium line λ4078 is strong are of about the same luminosity.

Classification of Stellar Spectra.

Suggestions have been prepared by Professor Russell, in collaboration with Mr. Adams, Chairman of the Committee on Spectral Classification of the International Astronomical Union, and Messrs. Merrill, Joy, and Hubble for an extension of the present notation for the classification of stellar spectra, which should enable most of the "peculiarities" at present recognized to be represented in a simple fashion, leaving very few cases out of reckoning. These suggestions will be submitted to the members of the committee for action previous to the next meeting of the Union.

CORRELATION OF LUMINOSITY WITH SPECTRUM AND COLOR.

The evidence bearing on the relations of absolute magnitude to spectral type and color index now available has been examined by Mr. Seares and Mr. Hubble in a search for criteria applicable to the determination of the distances of groups of stars involved in nebulosity. The data used were the spectroscopic parallaxes of Mr. Adams and his associates (1,646 stars), the helium stars of Professor Kapteyn (434), the visual binaries investigated by Jackson and Furner (556), the Cepheid variables with Mr. Shapley's determinations of absolute magnitude, and his results for more than a thousand giant stars in globular clusters. The chart illustrating the results for the first two of these groups is reproduced on page 270. Such groups as the Hyades, the Pleiades, and the Ursa Major stream were also considered; and finally correlations of color with apparent magnitude were examined for several clusters of unknown or uncertain distance and for a number of rich galactic fields. So far as the original purpose is concerned, the results are not wholly conclusive, but a number of interesting details were brought to light by plotting absolute magnitudes against spectral types, or their equivalent color indices, in the manner of the well-known diagram of Professor Russell. The curve of modal values for the helium stars runs smoothly into that of the dwarfs. The corresponding curve for the visual binaries has a different slope from that defined by the helium stars and the stars of the spectroscopic list, because of the use of a constant mass for the calculation of the hypothetical parallaxes of the binaries. The Cepheids and pseudo-Cepheids of our own system, in spite of high dispersion, present a correlation of mean color with luminosity similar to that shown by the Cepheids when absolute magnitudes are assigned in accordance with the period luminosity relation, and to that of the giant stars in globular clusters. Further, in certain rich galactic fields there is a parallel correlation of mean color with apparent magnitude (p. 265). The inference is that the stars in the galactic clouds are similar in luminosity to the Cepheids and pseudo-Cepheids of our own system and the most luminous stars in the globular clusters. Other details will be discussed in a forthcoming Contribution.

The complicated character of the diagram on page 273 raises a question as to how the frequency curve for all types together would agree with the luminosity and density functions determined by Professors Kapteyn and van Rhijn. Mr. Seares has derived from these functions an expression for the frequency curve of the absolute magnitudes of all the stars brighter than any limit of apparent magnitude, which can be compared directly with the results of observation. All things considered, the agreement is excellent. The only irregularity of importance arises from an exceptional congestion of K stars between $M=0$ and $M=+2$.

MASSES OF VISUAL BINARY STARS.

The examination of the data bearing on absolute magnitude has led Mr. Seares to a determination of the mean masses of visual binaries of the various spectral types. It is easily shown that the total mass of the system μ is given by

$$\log \mu = 0.3 - 0.6\ (M - M_c)$$

where M is the true absolute magnitude and M_c the value corresponding to the hypothetical parallax π_c, calculated in the usual manner with an assumed value $\mu = 2$. The results of Jackson and Furner (Monthly Notices, R. A. S., vol. 81, 2, 1920) provide values of M_c for more than 550 systems. The individual values of M are mostly unknown. But the mean absolute magnitudes for a group of binary systems will be the same, presumably, as that of a similarly selected group of non-binaries. Abundant material for the latter is available in the catalogue of spectroscopic parallaxes and the lists of helium stars whose luminosities were derived by Professor Kapteyn.

The results for the geometrical mean masses and the mean absolute magnitudes to which they correspond are in the accompanying table. The values for types earlier than A5 and for type M are affected by considerable uncertainty.

Spectrum.	Mean mass.	Mean M.	Spectrum.	Mean mass.	Mean M.
B0	18	−1.6	G0	1.7	+4.3
B5	14	−0.2	G5	1.3	+5.2
A0	10	+0.7	K0	1.2	+5.9
A5	7	+1.5	K5	1.1	+7.1
F0	4.4	+2.4	Ma	1.0	+9.8
F5	2.7	+3.3	....	....	....

For the later spectral types the masses are those of the dwarfs. About a hundred of the binaries occur in the list of spectroscopic parallaxes, and these fully confirm the rate of variation of mass with type for the interval F0 to K5.

STELLAR INTERFEROMETER.

INTERFEROMETER MEASURES OF STAR DIAMETERS.

In the last annual report a 20-foot interferometer, designed and built for use with the 100-inch telescope, was briefly described. The preliminary tests and adjustments of this instrument were completed in September by Messrs. Michelson and Pease. After Professor Michelson's return to the University of Chicago, Mr. Pease continued to make systematic observations, and on December 13 he succeeded in measuring the angular diameter of α Orionis. The fringes were found to vanish at a mirror separation of 10 feet, and, subsequently, corresponding determinations for α Boötis and α Scorpii were found at 21 and 12 feet, respectively. Assuming the mean wave-lengths for α Orionis and α Scorpii to be 5.75×10^{-5} cm., and for α Boötis to be 5.6×10^{-5} cm., the resulting angular diameters are:

α Orionis 0″.047, α Scorpii 0″.040, α Boötis 0″.022.

A definite decrease in visibility, without complete disappearance of the fringes, has been observed for α Ceti, α Tauri, β Geminorum, γ Draconis, and β Pegasi. β Persei, β Orionis, γ Orionis, α Leonis, β Leonis, α Lyræ, α Ophiuchi, α Aquilæ, α Cygni, and α Pegasi have been used as check stars, and in all cases show high visibilities with the maximum separation of the mirrors (19.6 feet).

At first all mirror settings were made by hand and much time was consumed in making the adjustments, but the subsequent installation of motor-driven screws, which move the outer mirrors simultaneously, has facilitated greatly the operation of the instrument. Larger mirrors are now being made for the interferometer, which will extend the range of observation to stars as faint as magnitude 3.5, and also insure more accurate settings on stars brighter than the present limit of 2.5 magnitudes.

Four important points should be mentioned in connection with the measurement of star diameters:

1. *Adjustment of the instrument.*—If fringes are observed on a closely neighboring check star, equality of path in the two pencils is certain; but if the check star is too far away (30° or more), flexure of the instrument may alter the adjustment in moving from one star to the other, and the equality of paths is no longer certain. For isolated stars a series of visibility measures is made on the star whose diameter is to be determined, beginning with the mirrors close together and increasing their distance, step by step, until the fringes vanish, and then returning a step or two until they reappear. The alterations in adjustment in this case are relatively small and the method is often used.

2. *Seeing.*—For final measures it is essential that the seeing be very good, as poor seeing leads to a disappearance of the fringes for separations of the mirrors less that corresponding to the true diameter of the star. On nights of bad and variable seeing, the visibility of the fringes may vary as much as 50 per cent or more in the course of a few minutes; and perfectly definite disappearances will be obtained on one night at mirror separations quite different from those determined on other nights, even when the decrease in visibility on each night is uniform.

3. *Light.*—Experiments with variable apertures show that for faint stars the fringes vanish for mirror separations that are systematically too small.

4. *Fringes.*— If the fringe pattern is too fine the fringes disappear, with increasing separation, sooner than when the fringes are wider.

Mention should be made of the patient and helpful assistance given by Mr. John Kimple in the troublesome adjustment of the mirrors.

Calibration of Visibility of Fringes.

In the hope of extending the possibilities of the stellar interferometer to stars whose angular diameter is too small to admit of observing the disappearance of the interference fringes, Professor Michelson, with the assistance of Mr. Pease, has made use of the device to which brief reference was made by him in his description of the instrument. For this purpose it is necessary, in the case of stars having a diameter sufficient to cause a distinct diminution in the visibility, to measure the visibility as a function of the distance between the outer mirrors. The diameter may then be calculated with an order of accuracy proportional to the accuracy of this measurement.

The method consists in the use of an auxiliary interferometer with a small fixed distance between the outer mirrors. A comparison system of fringes then appears in the focal plane of the observing telescope, in the present case the 100-inch reflector, and the visibility of these fringes may be altered in known ratio by altering the relative areas of the two apertures through which the auxiliary pencils of light from the star pass. If r is the ratio of the areas of these apertures, the visibility of the fringes is given by the expression

$$V=\frac{2}{r+\frac{1}{r}}.$$

After the two systems of fringes have been brought to equality, the stellar diameter can be calculated from the formula already given by Professor Michelson.

In the first trial of this method the apertures were squares 4.75 inches on a side, whose effective areas were varied by a sliding screen which covered one aperture as the other was uncovered. The ratio of effective areas accordingly is proportional to $\frac{s}{4.75-s}$, s being the width of one of the apertures. A number of observations showed the practicability of this plan, but presented the difficulty that when one of the apertures is nearly closed the light is drawn out by diffraction into a band which disturbs proper estimates of visibility. The use of a number of apertures was next tried, thus leaving the total intensity constant without altering the dimensions of the central image. A number of measurements was made in this way, but the total intensity of the light in the comparison fringes was found to be too small for work upon any but the very brightest stars. Accordingly it was decided to return to the original plan, but at the suggestion of Mr. Pease the modification was introduced of varying the area of only one aperture and keeping its form the same, whether square or circular.

With this arrangement the total intensity is not constant, but is greater than with the preceding forms of aperture. A series of observations on the stars α Lyræ, β Pegasi, and α Tauri showed that the method is capable of giving results with average errors of the order of 10 per cent or less if the seeing is good. The character of the seeing, however, affects the results materially. In the case of α Lyræ, at a time when the seeing was fair, an extrapolation of the visibility curve showed that this should cut the axis at a distance of 75 to 100 feet, while on another occasion, with poor seeing, the intersection fell at 50 feet. This shows the importance of a careful study of the effects of seeing on the vanishing point of the fringes. The following method is suggested for making measurements of the seeing, which to a great extent should be independent of the personal element.

Let a diaphragm be placed at a convenient distance within the focus and the aperture reduced until the diffraction rings appear. A provisional formula connecting the seeing S with the aperture d is

$$S = 10\ (1 - e^{-\alpha d})$$

where α is a constant to be determined by observation.

With the seeing measured in this way, the vanishing-point of the interference fringes, and hence the stellar diameter, can be corrected by application of the factor

$$1 + a \log \frac{10}{S}$$

The constant a is found by observation, preferably, on a star of no appreciable diameter.

Another plan, which may prove even more serviceable is to observe the point of disappearance of the fringes in the auxiliary system at every measurement. In this case the factor may be represented conveniently by

$$1 - a \log \cos \pi \frac{r}{2}$$

in which r is the ratio of the areas of the apertures in the auxiliary system when the fringes vanish, and a a constant to be determined by observation.

Interferometer Measures of Double Stars.

The rotating type of stellar interferometer devised by Mr. Anderson has been used by Mr. Merrill to measure the position angle and separation of two double stars, Capella and κ Ursæ Majoris.

The orbital elements of Capella derived by Mr. Anderson give a fair representation of Mr. Merrill's later observations on ten nights, thus showing that only small corrections to the elements will be required. The residuals in distance run up to 0ʺ.0035, but the definitive orbit, which will be computed when an accurate value of the period has become available from radial velocity observations, should give deviations for a night not exceeding 0ʺ.0005. Residuals of one degree may be expected in the position angles.

The duplicity of the known double κ Ursæ Majoris (A 1585) was independently detected by Messrs. Anderson and Merrill on March 1,

1921. The measured position angle was then 251°.9, the distance 0″.0836. Subsequent measures during March and April showed the distance to be decreasing at the rate of 0″.003 per month, and the position angle about one degree per month. Thus it appears that the components will approach much closer in the near future.

About 80 other stars have been examined for change of visibility with position angle of the slits. These include spectroscopic binaries, variable stars, stars with composite spectra, and some bright stars chosen at random. For two or three of these objects probable variations were noted, but for nearly all no change in visibility could be detected.

VELOCITY OF LIGHT.

In the autumn of 1920 Mr. Pease and Mr. Ellerman carried out some tests of the apparatus described in last year's report, using the Mount Wilson station and one located on the hills near Whittier. Although the return beam was observed, it became clear that more light was necessary and that the adjustment of the distant mirror was inadequate. It was also evident that the site selected for the distant station was unsuitable on account of the dust and haze prevalent over the San Gabriel Valley at low elevations.

As a means of avoiding the difficulty of frequent readjustments in securing a return of the light from the distant station, the following modification was devised by Professor Michelson. The light, instead of being returned directly by the distant mirror, which in the earlier plan had a radius equal approximately to the distance between the stations, is brought to a focus by a concave mirror 22 inches in diameter and 30 feet in focal length. The focal image is formed at the surface of a small concave mirror of 30-feet focus, whence the light retraces its path and an image is formed which would coincide with the slit source where it could be observed by the aid of a half-silvered plane parallel plate. In order, however, to avoid direct illumination of this plate and the revolving mirror, the return beam is received on another plane mirror, which allows it to be reflected from the opposite face of the revolving mirror.

This apparatus has been tested in a preliminary way between stations at the Pasadena laboratory and in the foothills at Altadena, a distance of 3 miles. As a second station to be used in connection with that on Mount Wilson for measurements of the velocity of light, a point has been selected on the San Antonio ridge near a lookout maintained by the Forest Service. The elevation of this station is 6,800 feet, its distance from Mount Wilson 22 miles, and atmospheric conditions appear to be exceptionally favorable.

THE RELATIVE MOTION OF THE ETHER.

If a pencil of light is divided into two parts by a half-silvered plate of glass and these are brought back to the starting-point by suitably placed mirrors, interference fringes are produced when the beams are reunited after having traversed very nearly equal paths in opposite directions. At the pole of the earth, and to a less degree at any other latitude, in consequence of the earth's rotation, the time interval for one of the pencils will be less than that for the other by an amount depending on the area included within the circuit. At a latitude of 35° the retardation in light-waves, and therefore the displacement of the fringes, will be of the order of one fringe per square kilometer of area. This result follows from the general theory of relativity as well as from the hypothesis of an ether fixed in space.

Should the result of the experiment show such a displacement, no decision could be reached. If, however, the displacement should be zero, or appreciably less than the calculated amount, it would show that the basis of the theory of relativity is incorrect and would prove the existence of a medium (ether) which is not stationary but is dragged along by the earth in its rotation either partially or completely.

The first requirement of such an experiment is that the fringes be visible over a very long path of light. With the apparatus set up on Mount Wilson at distances up to 700 meters, Professor Michelson found the fringes readily visible and measurable to within a few one-hundredths of a fringe. With a considerably larger circuit, about 3,000 meters, the fringes could not be seen. The investigation will be continued at the longest distances at which the fringes are visible.

Assisting Professor Michelson in this experiment were Messrs. Smith, Benioff, Richard Seares, and Drummond.

MAJORANA'S ABSORPTION OF GRAVITATION.

Majorana's theory of the absorption of gravitation in passing through matter leads to consequences with regard to the motions of the planets and the moon which are glaringly inconsistent with observation, unless it is assumed that the inertial mass, as well as the gravitational force, is diminished by the "screening" influence, and both in the same ratio. The phenomena of the tides show that, even on this assumption, any absorption of the sun's gravitational force within the body of the earth must be less than one five-thousandth as great as Majorana supposes.

Majorana's experiment (if the reality of the effect which he has observed is confirmed) may be explained on the assumption that the mass of a body (both inertial and gravitational) is diminished when another large body is brought near it; but direct interposition between the earth and the first body can not be essential for this effect.

ACCURACY OF PARALLAX DETERMINATIONS.

Formulæ have been developed by Professor Russell showing the accuracy with which the mean parallax of a group of stars can be found from their parallactic and peculiar motions. If the mean peculiar radial velocity of the stars is less than 14 km. sec., the parallactic motions give the more accurate result; if it is greater, the peculiar motions are more reliable.

Unless vitiated by some form of observational selection, the mean parallax derived from 10 stars should have a probable error of less than 25 per cent of its own value, and be significant. These conclusions are confirmed by a study of random groups of 10 stars of class B, taken from Campbell's list.

INVESTIGATIONS BY PROFESSOR KAPTEYN.

The last of Professor Kapteyn's investigations mentioned in the Year Book for 1920, p. 255, have been completed. The results, which deviate somewhat from those previously considered probable, are perhaps best appreciated from the accompanying table, which, though confessedly crude, is believed to represent fairly what at present can be learned about the arrangement of stars in distance.

Limits in parsecs within which the structure of the stellar system can be found.

Method.	Galactic latitude.		
	0°–20°	40°–90°	0°–90°
1. Direct parallax determination	....	....	50
2. Parallactic motion, now well known for stars to $m=10$	320	240	300
3. The same, to $m=13$	(830)	(610)	(720)
4. Parallactic motion, stars to $m=10$ and $\mu=0''.01$	400	320	360
5. The same, together with N_m (the latter to $m=14$)	1600	800	1200
6. The same, N_m to $m=17$	(4000)	(1600)	(2800)
7. Extension according to Point IV, N_m to $m=14$	3000	1000	2000
8. The same, N_m to $m=17$	(8000)	1700	....

In another investigation, which has also been completed, a first attempt is made at a complete theory of the arrangement and motion of the whole stellar system. It was found that if, for the equidensity surfaces derived in Contribution No. 188, we substitute a series of concentric similar rotation ellipsoids, similarly situated, the observations are still tolerably well represented. This property makes it highly probable that the total attraction of that part of the system which lies outside ellipsoid X (major semiaxis = 8,465 parsecs; minor semiaxis = 1,660 parsecs) on any point inside must be very small. Since the distribution of the stars within this ellipsoid is known, we can obtain a good approximation for the total attraction of the whole system on any point inside ellipsoid X, expressed in terms of the attraction of a star of average mass.

It is then shown that the system, if at rest, can not be in equilibrium. In order that the system may be in a steady state we must therefore assume that the stars have a systematic motion. Observation shows that such motion really exists and that it is parallel to the plane of the Milky Way. It is the motion of the star-streams. We are thus led to assume for the system a rotatory motion of some sort around the axis toward the pole of the Milky Way.

On this assumption the stars in the immediate neighborhood of the rotation axis have no systematic motion, and observation shows that the peculiar velocities are at least approximately distributed according to Maxwell's law. These stars are, therefore, in much the same circumstance as the particles of air in our own atmosphere, with the total attraction of the whole system in place of that of the earth. Further, the encounters of the separate stars must be relatively very scarce as compared with those of the molecules of the air.

Though such differences make it seem doubtful whether we are justified in applying to the stellar system the formula furnished by the kinetic theory of gases for barometric determination of altitudes, Professor Kapteyn has ventured to make such an application to the stars lying along the rotation axis. In this way he has been led to a determination of the following values of the average effective mass of a star:

Distance from center.	Average effective mass.
198 parsecs.	2.2 × sun's mass.
413	2.0
717	1.7
1114	1.5
1660	1.4

Since the attractive force which enters into the formula includes the attraction of any existing dark matter, and since the above masses represent total mass divided by total number of luminous stars, they have been called average effective masses. The good agreement of their values with what has been found for the masses from binary stars proves that the total dark mass in the system must be small as compared with the luminous mass.

In applying similar reasoning to the stars in the plane of the Milky Way the centrifugal forces must be taken into account. These forces have been determined in such a way that for regions of equal star-density on the rotation axis and in the plane of the Milky Way we are led to the same average effective mass. Once the centrifugal forces are known, the radial and linear velocities can be determined. The results for the latter are as follows:

Linear velocity in plane of Milky Way.

Dist. from center.	Linear velocity.
1010 parsecs	13.0 km. per sec.
2106	19.5
3657	20.1
5675	19.4
8465	18.6

For stars of intermediate galactic latitudes similar results are obtained in a somewhat different way.

It appears that for the greater part of the system the linear velocity is practically constant and equal to about 19.5 km. per sec. The direction of the rotation is indeterminate. If we assume that part of the system moves one way and the rest in the opposite direction, the relative velocity of the two groups, for the bulk of the stars, is 39 km. per second.

We are thus led, in a perfectly natural way, to a complete theory of the phenomenon of star-streaming, which agrees qualitatively and quantitatively with what we know about these streams. That the theoretical stream-lines are curved, whereas Professor Kapteyn has thus far supposed them to be rectilinear, offers no difficulty, if it turn out, as in all probability it will, that the sun is not very near the center of the system. For in this case the curvature of the stream-lines, within the domain of the stars which have served for the derivation of the star-streams, must be inappreciable.

Further consequences of the theory as well as a number of defects of this very provisional solution are outlined in a forthcoming Contribution.

PHYSICAL LABORATORY.

INSTRUMENTS.

The solenoid magnet for high fields, described last year as under construction, was assembled during the winter and tested. The cooling system proved to be adequate, the magnet carrying its full load of 4,000 amperes. Rough measurements indicated a field-strength of 33,000 gausses in the tubular space of 5 cm. diameter within the solenoid. After experiments, described later on, had been made with a vacuum furnace and then with a Stark-effect tube in the solenoid, the latter was dismantled, rewound, and considerable time spent in improving the kerosene-circulation system to guard against the accumulation of water, which tended to produce electrolysis, and sediment, which obstructed the flow. These changes having been made, the apparatus is again ready for service.

In order to study the effect of a magnetic field at different angles to the lines of force with reference to sun-spot phenomena, a second solenoid was constructed of copper tubing, water-cooled, the coil having an internal cavity of sufficient size to permit the rotation of a small furnace up to an angle of 60° to the lines of force. This solenoid, excited with 1,200 amperes, gives a field of about 8,000 gausses, and is especially adapted for the observation of absorption spectra.

The furnace with water-cooled contacts, constructed last year, having proved very effective for high-temperature work, a chamber was constructed so that it may be used as a vacuum furnace. This consists of a base-plate through which the current conductors and tubes for the water-cooling system are passed, and an iron hood which is lowered into position when all parts of the apparatus have been fully adjusted. With this furnace, tube temperatures above 3,000° can be maintained for long periods, and many phenomena, especially of absorption spectra, can be studied more effectively than heretofore.

The two high-tension transformers, producing voltages up to 60,000 and 100,000, respectively, have been completely overhauled. The 100,000-volt transformer has been provided with a new tank for oil insulation.

Messrs. Nicholson and Pettit have devoted some time to the design and construction of thermopiles and vacuum cells for use in laboratory, solar, planetary, and stellar problems. Special attention was paid to tellurium, which has given excellent results in vacuo when used in combination with silver and other metals. A preliminary study of the change of sensitivity with pressure gives similar effects in hydrogen, oxygen, and air, indicating that the entire change takes place between 1 mm. and 0.01 mm. pressure. Further studies will be made at lower pressures. Tests of the couples for the observation of the total energy curve across the sun's disk with improvised photometric apparatus have given satisfactory records.

ELECTRIC-FURNACE INVESTIGATIONS.

The following studies of electric furnace spectra were carried out during the year by Mr. King.

Manganese.

The material previously collected was supplemented by some additional spectrograms and prepared for publication. In the interval λ2795 to λ6605, 270 manganese lines were classified according to their changes, with temperatures varying from 1560° to 2400° C. The search for manganese furnace-lines was extended as far as λ8200. Besides the usual classification, the special features exhibited by noteworthy lines at different temperatures were described.

Scandium.

The acquisition of a small quantity of the rare element scandium in the oxide form made possible the study of the furnace spectrum of this element, which was highly desirable on account of the prominence of scandium in the sun. Furnace spectrograms were made at 2000°, 2250°, and 2600° C. for the interval λ3000 to λ6600; 307 lines were classified according to intensity at the three furnace temperatures and in the arc. Special interest attaches to the enhanced lines and to those strengthened at low temperatures. In the sun, only the enhanced lines of scandium are well marked in the disk spectrum, the arc lines in general being very faint. Though usually absent from the solar disk, the low-temperature lines are strong in the spot spectrum.

The furnace experiments show the enhanced lines to be of a type intermediate between those of titanium and the H and K lines of calcium, requiring only moderate excitation, some of them showing in the furnace at 2250°. This was indicated by Fowler's work, but the furnace experiments have yielded much additional information, as many lines of this type are faint in the arc and can be advantageously observed only with the furnace. The band spectrum of scandium was found to be due probably to the oxide.

The low-temperature lines undergo a wide magnetic separation in sun-spots, so that when laboratory data are available these lines will be useful in the study of spot fields.

Absorption Spectra.

The use of the furnace as a source for absorption spectra, the incandescent background being given by a plug at the center of the tube, has been continued. The main objects were the production of absorption spectra comparable in richness with the emission spectrum, and the observation of the relative reversibility of different classes of lines. Higher temperatures were employed than formerly, plug temperatures above 3200° C. sometimes being used. With iron, practically the whole furnace spectrum was thus obtained in absorption as far as λ6700. The iron lines to the red of λ5500 are difficult to reverse in laboratory sources. Hitherto they have been obtained as absorption lines only in the explosion spectrum.

A detailed comparison was made of the iron spectrum in emission and absorption at different temperatures. When supplemented by experiments now in preparation, these results will show clearly the connection between the susceptibility of a certain type of line to reversal and its general laboratory behavior. The high temperatures which may now be used permit the study of lines in absorption which in the usual sources show no tendency to reverse. The development in absorption of the high-temperature arc lines (Class III) is of special interest. An extension into the ultra-violet has also been obtained, the absorption spectrum of iron having been carried to λ2448.

Absorption spectra of the alkali metals, including the subordinate series of sodium, potassium, and cæsium, have also been produced in the furnace. The principal series lines of these substances had previously been observed in absorption, but not those of the subordinate series. The furnace shows, however, there is no difficulty in producing these series beyond that of using a sufficiently high temperature in vacuum.

The sharpness of these furnace absorption lines, as compared with their diffuse and often very unsymmetrical structure in the arc, showed that improved wave-lengths could be secured and, consequently, that the values of the series constants could be improved accordingly. Spectrograms for this purpose with iron-arc comparison were made and measured.

Ultra-Violet Spectrum of Iron.

Approximately 1,000 lines of wave-lengths shorter than λ3885, the limit of the list previously published, and extending to λ2448, have been identified in the furnace spectrum of iron and classified according to intensity at different temperatures and in the arc. In spite of the complexity of the iron spectrum, certain types of lines are very definitely selected in this way, and the similarity can be used as a basis in studying the structure of the spectrum. The arc spectrum in the ultra-violet was also studied with regard to the variation from pole to pole of different types of lines. Their behavior is definitely connected with their appearance in the furnace.

Miscellaneous.

Furnace spectrograms for yttrium, neodymium, and zirconium have been made to supplement former material on the rare-earth spectra. The cadmium spectrum also has been photographed at different temperatures. The silicon line λ3906, important in stellar spectra, was examined and found to show about the same response to temperature change as the iron lines of Class III.

Observations of the Zeeman Effect.

Both the solenoid magnets with their respective furnaces were given preliminary trials by Mr. King to test the action of the apparatus. The solenoid of water-cooled tubing was used with the contained furnace at various angles to the lines of force. Most of the tests were on absorption spectra, the spectrograph being provided with Nicol and compound quarter-wave plate. The effect of variable inclination of magnetic field in sun-spots could thus be imitated.

The solenoid for high fields was used with vacuum furnace. Only a few trials were made before the magnet was adapted to the Stark-effect experiments, but some promising spectrograms were obtained, the vacuum furnace giving a temperature of 2400° C. without excessive heating of the parts. The magnet and furnace thus seem well adapted to the study, under high fields, of the lines given with special strength by the furnace.

COMBINED EFFECT OF ELECTRIC AND MAGNETIC FIELDS ON RADIATION.

Reference has been made in previous reports to our inability to detect any evidence of the Stark effect in the sun-spot spectrum. During the past year Mr. Hale, assisted by Mr. Sinclair Smith, has undertaken an investigation of the combined effect of electric and magnetic fields on radiation. If, in spite of present indications, an electric field exists in sun-spots, its influence on the light emitted will be exercised simultaneously with that of the magnetic field. For this reason, and in view of the important bearing of the combined effect on theories of the structure of the atom, an extensive study of this problem seems to be warranted.

A powerful solenoid magnet, designed by Mr. Anderson for use with currents up to 4,000 amperes, offered within its hollow core precisely such conditions as our needs demanded. In the uniform field of 33,000 gausses a vacuum, tube of pyrex glass, giving a strong electric field just in front of the cathode, within the limits of the Crookes dark space, was inserted. The discharge was produced in hydrogen by a small transformer, used in conjunction with a mechanical rectifier, which gave a high-voltage current sufficiently steady for preliminary purposes. Under these conditions (lines of electric and magnetic force parallel) the appearance of the $H\gamma$ line was nearly the same in the electric field as in the combined field, though in the latter case the components were more diffuse. It remains to be seen whether the components will show further resolution under higher dispersion and in a steadier electric field. Some of the lines of the secondary spectrum indicate distinct differences in intensity in the electric and the combined fields. The investigation is being continued with a special form of quartz tube, designed for heavy discharges. Improved apparatus for high-potential direct current has also been provided.

Another mode of approach to the problem of electric fields in sunspots is afforded by Saha's ionization theory, which should permit an upper limit to be set for any field that may be present. Available data, such as the weakening of the enhanced lines, indicate that if an electric field exists there it must be weak.

WAVE-LENGTHS OF IRON-ARC LINES FROM λ3370 TO λ6759 MEASURED WITH GRATING AND INTERFEROMETER.

A list of 1,026 iron-arc lines has been published by Messrs. St. John and Babcock, of which 976 were measured on from 1 to 62 grating spectrograms and 576 on from 1 to 39 interferometer plates. The agreement shown indicates that for most of the lines the weighted mean wave-length is accurate to 0.001 A. To avoid errors due to pole effect and to obtain sharp lines, a 12-mm., 5-ampere Pfund arc was used. To eliminate instrumental errors, spectrograms were made with two Michelson and three Anderson gratings and with four pairs of interferometer plates.

In the case of stable lines the agreement with the results obtained at the Bureau of Standards is good, but for lines of groups *c*5 and *d*1 the Bureau of Standards measurements are systematically greater. The mean difference for 46 lines is +0.007 A, due to the large pole effect in the center of the 6-mm., 6-amp. arc. Of 78 International Secondary Standards measured with the interferometer, the 62 stable lines came out as follows: 53 within ±0.001 A, 8 within ±0.002 A, 2 within ±0.003 A, and one within 0.004 A of the adopted values, while in the case of the 16 standards belonging to groups *c*5 and *d*, the international values are systematically greater in the mean by 0.007 A, due to the large pole effect in the arc used in the original determination. Though the wave-lengths given by the 6-mm. 6-ampere arc may be employed as standards in cases where the highest accuracy is not required, neither these nor the standard wave-lengths of similar lines can be used for determining the differences between their solar and terrestrial wave-lengths when both are expressed in the international system, since solar lines are produced under conditions in which pole-effect is not involved.

With the exception of further work in the violet and red, and determinations for certain iron lines corresponding to faint solar lines, the program on iron-arc wave-lengths has been concluded. A wide range in wave-length and in line-intensity is necessary for our investigation of the Einstein effect and for separating the causes contributing to the shift of solar lines.

PRESSURE DISPLACEMENTS OF IRON LINES.

The investigation of the pressure effect for certain iron lines by Mr. Babcock promises results of considerable interest. Previous studies of this subject have been concerned for the most part with large differences of pressure and have yielded data of great value. But the influence of pole-effect on such observations and the fact that with increasing pressure the spectral lines are not only displaced but are widened make it highly desirable to attack the problem anew, using a small difference of pressure and taking care to avoid the presence of pole effect as far as possible. The minuteness of the change in wave-length to be observed under these conditions requires a method quite free from the effects of thermal and mechanical disturbances. The Fabry-Pérot interferometer has been found to meet these exacting requirements when used by what may be called the differential method. Simultaneously with each exposure to the iron arc the light from a Cooper-Hewitt mercury lamp is passed through the interferometer and photographed upon the same plate. The optical arrangements are chosen so that full illumination is secured for from 15 to 30 interference rings upon each spectral line. For two plates taken at different pressures the difference in wave-length for any spectral line is given by *each pair* of homologous rings, the rings on a single mercury line serving to eliminate all instrumental changes. On account of the large number of rings available on each line, a single exposure acquires very high weight. The accuracy of the method is well illustrated by numerous groups of observations taken in sets of three instead of in pairs. When the three photographs of such a set are intercompared, three differences of wave-length are obtained corresponding to the three differences of pressure employed. The sum of two of the differences should equal the remaining difference, and in practice this is found to be so within 0.0001 A. Representative lines belonging to various groups in the Mount Wilson classification are under observation, the range of wave-length being λ3900 to λ6500. The pressures are read on a mercurial manometer held constant within 1 cm. during an exposure; the values chosen include points at frequent intervals within the range from zero to one atmosphere. At present the observations are not complete enough to admit of satisfactory discussion, but there is no doubt that for the sensitive lines of groups *c* and *d* the values of the pressure displacement obtained in this way are markedly lower than those of former observers. The difference may be ascribed to the lessened influence of pole-effect in our method of observing. The program includes an examination of the effect of change of atomic weight of the surrounding gas, using hydrogen and helium instead of air, the study of modifications in the sources, and the possible application of other types of interference spectroscopes to the measurement of these minute displacements.

ABSORPTION SPECTRA OF ELECTRICALLY EXPLODED WIRES.

The work on absorption spectra by the method of electrically exploded wires has been continued by Mr. Anderson with the assistance of Mr. Sinclair Smith. High-dispersion spectrograms of the iron spectrum from λ2600 to λ6600 have been made with the 15-foot concave grating. These show a wealth of detail, and complete study of them will require some time. Perhaps one of the most interesting facts brought to light is that the motion toward the observer of the absorbing vapors surrounding the explosion causes all the absorption lines to be displaced toward the violet, but by different amounts for different classes of lines. In general the displacement is greater for high than for low-temperature lines.

For the further development and extension of the work, it is desirable to have a condenser suitable for voltages up to 100,000 or more. Condensers of this type are not available at present, except by series connection of low-voltage units. Investigation shows, however, that a condenser of the required capacity made up of series units would be exceedingly costly, and experience indicates very positively that it would not function satisfactorily. Units capable of working at 100,000 volts therefore appear to be a necessity. A good deal of study has been given to this problem, and it is hoped that a satisfactory solution is in sight.

MISCELLANEOUS INVESTIGATIONS.

Messrs. Anderson and Smith have done some work on the effect of passing the discharge of the large condenser through vacuum tubes. This promises to be a powerful method of developing the enhanced lines of the gas in the tube, and it also brings out the enhanced lines of the electrodes. Interesting preliminary results have been obtained for oxygen, nitrogen, and iron. Through the courtesy of Admiral Griffin a quantity of helium has been obtained from the Bureau of Steam Engineering of the U. S. Navy, and a study of helium, hydrogen, and perhaps other gases will be undertaken.

Messrs. Anderson and Babcock have commenced a study of the transmission of the atmosphere for short wave-lengths. The spectrum of an iron arc burning on Mount Wilson is photographed by means of a quartz spectrograph in Pasadena. The air-path has a length of 7 miles and is equivalent to 1.4 atmospheres. The trials so far made have been under poor conditions, due to the prevalence of very thick haze. Nevertheless, λ2740 has been recorded with an exposure of one hour, although, as is well known, the solar spectrum ends at λ2890.

The chemical identification of the air-lines in spark spectra in the region λ5927 to λ8683 have been made more complete by additional experiments involving exposures to the spark in pure oxygen. The photographs were secured by Messrs. Clyde R. Keith and F. L Hopper under the direction of Mr. Merrill. The work confirmed the preliminary results from this laboratory, as well as those obtained by other observers using vacuum tubes, and added some identifications not previously available.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

The work of drafting and design has covered a wide range, as new instruments and appliances are frequently needed in all branches of the Observatory's activities. The following attachments were designed for the 100-inch telescope: extra-focal interferometer, Cassegrain spectrograph VI, Cassegrain spectrograph VII (for red end of spectrum), motor drive for mirrors of 20-foot interferometer, diaphragm for end of tube, focusing apparatus for Newtonian plate holder, minor improvements of dome and mounting, silvering appliances, instrument cabinets, etc. Work for the 60-inch telescope included designs for intensifier lens, modification of quartz spectrograph, finder mounting, wind-screen motor mounting, and changes in counterweights. Alterations of the Snow telescope involved improvements in the concave-mirror mounting and speed reduction of the windlass. A new focal-plane shutter and a plate-holder for the 13-foot spectroheliograph were designed for the 60-foot tower telescope. Work for the laboratory included improvements of the large solenoid magnet and attachment, a vacuum furnace and hood, photographic recording apparatus, and quartz tubes for the Stark effect. Other designs were for a stereo-comparator micrometer, mirror mountings for the velocity of light apparatus, and various minor appliances. One draftsman's time during about ten days per month is required for illustrations of Observatory publications. The work has been done by Messrs. Pease, Nichols, and Kinney.

OPTICAL SHOP.

The work of the optical shop has included the grinding and figuring of the following mirrors: two 7.25 by 9 inch, plane; three 12-inch diameter, plane; two 8-inch diameter, plane; one 4.5-inch diameter, plane; one 14-inch concave mirror of 15 feet radius; also one 2-inch quartz concave lens; optical parts for eight binocular eyepieces; quartz disk for double-star interferometer; speculum-metal plates for gratings; many small prisms and lenses. The following machines were designed and partly completed: 6 spindle machines for lens work, small edge grinder, optical testing apparatus. The work was done by Messrs. Kinney and Dalton.

GLASS-BLOWING SHOP.

A small shop for making blown glass and quartz apparatus for spectroscopic and other purposes was equipped in July. Mr. D. J. Pompeo, formerly with the Cooper-Hewitt Company, will devote part of his time to this work. He is now making quartz tubes for use in the study of the combined effect of magnetic and electric fields on radiation.

INSTRUMENT SHOP.

The chief work of the instrument shop (Mr. Ayres, foreman) includes: stereocomparator, large and small solenoid magnets, velocity of light apparatus, 20-foot interferometer changes, extra focal interferometer, vacuum chamber for large electric furnace, photographic recording apparatus, glass-blowing equipment, spectrograph and concave-mirror mounting of Snow telescope, 8 by 10-inch plate-holder for 60-inch telescope, attachments for 10-inch refractor, binocular eyepieces; and the following attachments of the 100-inch telescope: Newtonian mirror mounting, Cassegrain spectrograph VI, plate-holder, cage clamp, declination slow-motion, traveling crane, observing platforms, dome shutter, silvering equipment, instrument cabinets. Much miscellaneous work was done on instrument repairs, construction for the laboratory and optical shop, building repairs, and various minor items.

RULING MACHINE.

The accidental errors causing false spectra in the gratings ruled last year were found to be due to the spacing mechanism. A new mechanism designed and built by Mr. Jacomini this year has proved to work perfectly, and the accidental errors appear to be completely removed. The ruling carriage has been rebuilt and made very much lighter, thus adding materially to the smoothness of operation of the machine.

There remains now a small and quite regular periodic error due to slight residual eccentricities in the spacing wheel and the screw pivots.

The actual size of this error is $\frac{1}{250000}$ inch, and it could be removed by a correcting mechanism. It has been decided, however, to attempt its removal by correcting the eccentricities directly, a method which, if successful, will make the adjustment more permanent than if a correcting mechanism is employed.

Buildings and Miscellaneous Construction.

The only two buildings erected on Mount Wilson during the year were an underground concrete chamber for constant temperature conditions in sensitizing plates for the red and infra-red and a temporary pier and shelter used by Professor D. C. Miller for his experiments on ether drift. The work of repair included painting the 150-foot tower telescope tube, several of the cottages, and the woodwork of the Monastery, laboratory, and power house. Brick chimneys have been built in three of the smaller cottages in order to reduce the risk of fire.

NUTRITION LABORATORY.[1]

FRANCIS G. BENEDICT, DIRECTOR.

When the Nutrition Laboratory was established there already existed several well-endowed, adequately manned, and highly productive organizations for medical and pathological research. It was accordingly felt that the efforts of the new Laboratory would best be directed toward studies of pure physiology, particularly human physiology, for it was the consensus of opinion that human physiology, especially studies of heat-production and gaseous transformations in the body, had such significance in its relation to general physiology that it should no longer be relatively neglected.

Shortly after the opening of the Laboratory a pronounced departure from this general thesis was made by instituting a research on diabetes, in collaboration with Dr. Elliott P. Joslin, of Boston. This procedure has been fully justified by the extraordinary degree of cooperation given to it by Dr. Joslin, not only in the scientific conduct of the investigation, but in the actual financing of the undertaking, as well as in the preparation of reports. The selection of this special topic for investigation was particularly appropriate, since diabetes, like almost no other disease, is amenable to treatment and control only through dietetic measures. The two monographs already printed by the Institution have been supplemented by several medical papers and two books by Dr. Joslin, and a third monograph in the series is now in preparation.

In addition to these positive contributions to the field of medicine, there has been in recent years a utilization by the medical profession of much of the abstract physiological data accumulated by the Laboratory staff and by a large number of volunteer workers at the Nutrition Laboratory during the past 14 years. As the resultant of all internal glandular and muscular activities incidental to the maintenance of life is heat, its measurement gives the best expression of the intensity of vital activity. Accordingly, the Laboratory early entered upon a survey of the heat-production of the quiet, normal human body from birth to old age. This was undertaken primarily as a study in pure physiology and proceeded to such an extent as to provide material for a somewhat elaborate biometric treatment by Dr. J. Arthur Harris, which has been published by the Institution. These data have been extensively used by physicians as standards for comparison with pathological measurements.

The techniques employed in the study referred to were somewhat complicated. Since in certain diseases, notably those involving the thyroid gland, there are marked changes in the level of heat-production, the physician requires some relatively simple method for measuring the output of heat. A technique has recently been developed in the Laboratory by which it is possible to compute heat-production with great accuracy by the relatively simple measurement of the oxygen consumption in respiratory processes during periods as short as 10 to 15 minutes. This apparatus, which for obvious reasons has not been patented and hence can be freely manufactured by any one, is now being supplied in large numbers by several manufacturers to hospitals and clinicians.

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[1] Situated in Boston, Massachusetts.

The whole subject of the measurement of heat-production under standard conditions, that is, the determination of the so-called "basal metabolism," has awakened great interest, this being evidenced by the fact that at the meeting of the American Medical Association in Boston (June 1921) a symposium on the subject was attended by over 1,200 physicians. It is most gratifying to all workers in the field of pure physiology to feel that these efforts, undertaken with no immediate thought of practical application, are meeting the needs of the physician.

ADDITIONS TO EQUIPMENT.

Dreyer stadiometer.—An apparatus similar to that devised by Professor Georges Dreyer, of Oxford, England, has been constructed by Dr. Miles for measuring with the greatest degree of accuracy the sitting and standing heights. These two factors are assuming great importance in determining the normality of individuals.

Haldane portable gas-analysis apparatus.—For the increased number of gas analyses needed in his extensive researches, Dr. Carpenter has installed a motor-driven arrangement of levers for raising and lowering mercury leveling bulbs, so that it is now possible to conduct analyses with seven Haldane apparatus at one time.

Respiration apparatus for small laboratory animals.—In connection with a projected research upon the basal metabolism of the white rat, an apparatus was designed and constructed giving accurate measurements of the carbon-dioxide production and oxygen consumption of the white rat. This employs the well-known closed-circuit principle so long in use in this Laboratory. The apparatus has been subjected to the severest tests, entirely reconstructed, and is now ready for installation in the Department of Nutrition of the School of Practical Arts, Teachers College, Columbia University, where a cooperative research is planned for the coming year.

An emission calorimeter for humans.—By employing the same type of compensation device used for the study of the energy transformations of geese during the conversion of carbohydrate to fat, two large chambers, each of a size suitable for observations on man, have been developed, with the view of using this type of calorimeter for observations on adults. The construction and testing of the apparatus are rapidly progressing.

Minor apparatus.—The static control recorder of Dr. Miles, briefly described in the annual report for 1920, has been duplicated.

Extensive experience with the new portable respiration apparatus devised in conjunction with Mr. Warren E. Collins, former mechanician of the Laboratory, has shown during the past winter the most advantageous use of a kymograph for writing the character of the respirations. Likewise a simple though extraordinarily efficient method has been developed for testing for a leak—an ever-present possibility in the use of all respiration apparatus.

A simple, home-made respiration apparatus was devised and exhibited at the Harvard Medical School.

COOPERATING AND VISITING INVESTIGATORS.

Dr. Elliott P. Joslin, with a number of his personal assistants and members of the Laboratory editorial and computing staff, is preparing a final report on diabetic metabolism with varying diets.

Dr. Howard F. Root, associated with Dr. Joslin, has actively cooperated with Dr. Miles in certain physiological and psychological tests on diabetic patients, as well as in taking blood samples for several subjects used in the research on the effect of alcoholic beverages.

Dr. Paul Roth, at the Battle Creek Sanitarium, Battle Creek, Michigan, has continued his tests of the new portable respiration apparatus and has contributed one or more medical papers on this subject.

Dr. H. Takahira, of the new Nutrition Institute of Japan, in Tokyo, made a visit of several weeks to the Laboratory for the study of the clinical chamber apparatus devised in the Laboratory and constructed by Mr. Collins. The study was made in anticipation of the installation of this apparatus in the Japan institute.

Professor E. G. Ritzman has continued the studies on the energy requirements of large animals with the new respiration apparatus in the Agricultural Experiment Station at Durham, New Hampshire. Frequent conferences with Professor Ritzman and Director John C. Kendall have resulted in the most active continuation of experimental work in this field.

Dr. C. G. Abbot, Assistant Secretary of the Smithsonian Institution, Washington, D. C., became much interested in studying the problem of radiation from the nude human body, and spent a week at the Laboratory with a honeycomb pyranometer, making a series of observations.

Among numerous foreign visitors, especial mention should be made of the stimulating conferences with Professor F. Gowland Hopkins, of Cambridge, England, Dr. G. von Wendt, of Helsingfors, and Professor T. Thunberg, of Lund.

STAFF NOTES.

Following the usual custom, Dr. Miles prepared an extensive confidential report of his foreign trip of 1920, which represents the eighth volume of this series of reports. Inasmuch as these volumes are illustrated by many photographs and give the results of personal surveys of the several scientific laboratories, the series forms an unusual record of development in laboratory construction, technique, and output.

After many years of successful and profitable assistance in the Laboratory, particularly in observations on the metabolism of children and in the making of delicate gas analyses, Miss Alice Johnson resigned from the Laboratory staff in the spring of 1921.

INVESTIGATIONS IN PROGRESS.

Breathing, gaseous exchange, and metabolism asleep and awake.—In a previous research upon the metabolism in rectal feeding, it was found that when the subjects fell asleep during the periods of observation there was a marked change in the volume of lung ventilation and in the relation between the volumes of carbon dioxide and oxygen. During the past year a systematic attempt has been made by Dr. T. M. Carpenter to study the character of the breathing, the quantitative relationship in the gaseous exchange and the metabolism, with medical students and other individuals as subjects. The experiments were conducted in all cases with the subject in the post-absorptive condition and between the hours of 9 a. m. and 1 p. m. Usually the length of the observation was about two hours, divided into from 12 to 15 periods. Most of the 26 subjects were drowsy or asleep at least part of the time. The respiratory exchange was determined by the gasometer method, the expired air being collected in continuously succeeding periods by means of two 100-liter Tissot spirometers and analyzed by means of the Haldane portable gas-analysis apparatus. Periodic heart-rate counts were made and continuous records of the respiration-rate and absence of activity were obtained. A graphic control of the drowsiness and sleep was secured. Mr. W. M. Konikov assisted in the experiments. The investigation is being continued.

Composition of urine as affected by ingestion of 2.75 per cent alcohol.—In the research conducted by Professor W. R. Miles upon the physiological effect of the ingestion of 2.75 per cent alcohol, the urine was regularly collected in periods of 15 to 30 minutes from immediately preceding the ingestion of the liquid until at least 2 hours after this time. Dr. Carpenter took advantage of this fact to determine the influence, if any, of this dilution of alcohol upon the elimination of chlorides, nitrogen, and total sulphur by the kidneys. The urines of 14 days with alcohol and those of 10 control days were analyzed. The chlorides were determined in nearly all of the samples, the nitrogen in the majority of them, and the total sulphur in a smaller number.

The results are of value in showing the possible changes in the urinary elimination of chlorides, nitrogen, and total sulphur in very short periods under normal conditions, also the effect of 2.75 per cent alcohol upon the excretion of these substances. The investigation is being continued. The analyses were made by Mr. W. M. Konikov, assisted by Mrs. H. Konikov.

Comparison of basal-metabolism apparatus.—Continuing his extensive series of comparison tests, Dr. Carpenter made several comparisons between the portable respiration apparatus, the gasometer method of determining respiratory exchange, and the Jones metabolimeter, with reference to the accuracy of the oxygen-absorption measurements by these methods.

The effect of alcoholic beverages containing 2.75 per cent alcohol by weight.—In continuation of the work interrupted by Dr. Miles's foreign trip in 1920, a further series of experiments has been made on the subject who served previously, to find whether these later results would confirm those already obtained, or whether there was a measurable influence from practice and tolerance, and also to compare the effect of different beverages. Afterwards the same routine was carried out with five young men during a 6-day series of experimental sessions. On the first two days alcohol was taken, but these tests were only for practice. Of the last four days, two were normal and two alcohol days. In all the experiments urine samples were collected, usually at 30-minute and occasionally at 15-minute intervals; these were later analyzed for alcohol concentration by the Widmark-Nicloux method. Dr. Miles was assisted in the neuro-muscular tests by Mr. E. S. Mills and in the chemical analyses by Miss Jane L. Finn, Mr. W. M. Konikov, and Miss E. L. Frutkoff.

Comparison of the percentage of alcohol in venous blood and in urine.—But little literature has appeared with regard to the relationships between the percentages of alcohol in venous blood and in urine. In connection with several of the observations on the effect of alcohol, Dr. Miles has made determinations of the alcohol present in both fluids. Usually four blood-samples were taken from arm veins within 2 hours after alcohol was taken. Urine was passed about every 15 minutes and certain of the urine samples were coincident with the blood samples. Dr. Howard F. Root assisted Dr. Miles in taking the samples, and the analyses were made with the assistance of Miss E. L. Frutkoff and with the help and criticism of Dr. T. M. Carpenter and Mr. W. M. Konikov.

The physiological and psychological fitness of diabetic patients.—The emphasis by Professor Georges Dreyer, of Oxford, on the use of four measurements, i. e., weight, chest-girth, sitting-height, and vital capacity, as indices of physical fitness has led to the adoption of these measurements by Dr. Root and Dr. Miles in determining the physical fitness of a series of diabetics at the Deaconess Hospital. Accompanying these measurements were a number of psychological observations in which the subjects were tested both in groups and individually, for diabetics frequently complain of loss of memory and inability to concentrate attention. The results are compared with like measurements of normal subjects and also with those for the group of young men in the large undernutrition study conducted by the Nutrition Laboratory in 1917–18.

Changes of muscle tonus with exposure to cold.—The changes in oxygen consumption noted under different conditions of temperature environment might be accounted for by variations in muscle tonus. Dr. Miles has cooperated in this phase of a research on temperature environment and, by using the patellar reflex and certain other means, has objectively recorded the changes in muscle tonus which occur when the subject disrobes and sits in a cool room for 2 hours or so, during which time measurements are made on the portable respiration apparatus.

The metabolism of young girls.—The series of observations on Girl Scouts, referred to in previous reports, has been supplemented during the past year by a study of two groups of Girl Scouts, one of 14 years and one of 18 years of age. Special arrangements were made for securing the pulse-rate throughout the entire night by the attachment of a stethoscope over the apex of the heart of each subject. The insensible perspiration was most carefully recorded, as well as the basal metabolism. This study supplements admirably the former year's work with younger children. The research was carried out with the cooperation of Miss Mary F. Hendry and Miss Marion L. Baker, and the extraordinary cooperative spirit of the Massachusetts Girl Scouts made the selection of groups of girls of these ages most satisfactory.

Temperature of the skin.—One of the factors contributing to loss of heat from the body is the relation of the temperature of the skin to the environmental temperature. Studies on this subject were continued with the special technique developed at the Laboratory, attention being given primarily to observations in which a nude subject was exposed to blasts of air from an electric fan at different velocities and different environmental temperatures. The details of the measurements were chiefly in the hands of Miss Alice Johnson and Miss Marion L. Baker.

Influence of environmental temperature upon metabolism.—This research, which has been in progress for several years, was continued with the same subject, special emphasis being laid upon the heat-losses and the metabolism under different conditions of environmental temperature and wind velocity.

Radiation from the human body.—The great changes in skin-temperature with exposure to low environmental temperatures and the great difference in skin-temperature at different parts of the body make a study of the radiation from the body desirable. Thanks to the cooperation of Dr. C. G. Abbot, a large number of observations of the direct radiations from the nude human body at different temperatures and at different parts of the body were made in the spring of 1921.

Influence of food upon metabolism.—The selection of a light though satisfying meal, that can be given hospital patients and even normal subjects, which would eliminate the 12-hour fasting period commonly required for metabolism measurements, is greatly to be desired. Taking advantage of the quite unusual degree of repose of the artist's model used in many of our other respiration experiments and studies, we have been making studies upon light diets, and noting their influence upon metabolism. These studies were made with the cooperation of Miss Marion L. Baker.

Conversion of carbohydrate to fat in the animal body.—This particular phase of nutrition has been studied for several years, and the extraordinarily high respiratory quotients observed have been tested by two entirely independent methods. The calorimeter for direct measurements of heat under these conditions has been further improved, and, as has been previously stated, the general principle is shortly to be applied to human calorimetry. Miss Alice Johnson assisted in this study.

Metabolism during mental effort.—A renewed interest in the effects of mental work upon physical condition, which have been so universally noted, has led to the institution of a research upon the relation between mental effort and metabolism. New technique, with graphic registration of respiratory depth and rhythm, promises most interesting results.

Metabolism of farm animals during growth.—In cooperation with Professor E. G. Ritzman, of the New Hampshire Agricultural Experiment Station, Durham, New Hampshire, and using the large respiration chamber installed in Durham by the Nutrition Laboratory, an extensive series of investigations has been under way during the entire year, in which observations have been made of the growth changes of calves and particularly of sheep. Several groups of ewes before and during pregnancy have also been studied. The work is still in progress. Professor Ritzman is assisted by Miss Helen L. Hilton.

Metabolism of birds.—This research, which has been conducted at the New York Zoological Park, through the cordial cooperative spirit of Director W. T. Hornaday and Mr. L. S. Crandall, the curator of birds, has been completed and the apparatus returned to the Nutrition Laboratory. The observations were in the hands of Mr. E. L. Fox.

Metabolism of snakes.—A review of the earlier observations made at the New York Zoological Park on the metabolism of snakes, particularly during the digestive cycles and with differences in environmental temperatures, showed several important points which needed further experimental evidence, and advantage was taken of the installation at the New York Zoological Park of supplementing the earlier data. These observations were made by Mr. E. L. Fox during the academic year 1920–21. The entire apparatus has now been removed and it is with regret that we announce the conclusion of this most ideal cooperative investigation.

PUBLICATIONS.

The following publications have been issued during the present year:

(1) Metabolism and growth from birth to puberty. Francis G. Benedict and Fritz B. Talbot. Carnegie Inst. Wash. Pub. No. 302 (1920).

From 200 to 300 children of both sexes were studied at the Massachusetts Wet-Nurse Directory and at the New England Home for Little Wanderers, with carefully tested and approved apparatus. In this report of the results considerable stress is laid upon the normality of these children, as indicated by the weight-to-age, height-to-age, and weight-to-height ratios. For comparison a large number of boys and girls in private schools were also measured. These comparisons throw most interesting light upon school life as affecting the growth factors. Pulse-rate and rectal temperature were secured for most of our intensively studied children and form the basis of a consideration of normal values. Naturally, the major part of the research dealt with the measured basal metabolism as affected by growth and age. Special treatment is given the relationship between the heat-production per unit of weight and that per unit of surface-area. The influence of sex, especially in the prepubescent stage, is considered. Finally, several methods for the prediction of the basal metabolism of children are discussed, and estimates given as to the probable total 24-hour requirements. Of general interest is the conclusion that, aside from digestive derangements, it is practically impossible to overfeed the growing child.

(2) A clinical apparatus for measuring basal metabolism. Francis G. Benedict and Warren E. Collins. Boston Med. and Surg. Journ., vol. 183, p. 449 (1920).

The great obstacle to studies of respiratory exchange has been the necessity for a complete equipment for gas analysis. To avoid this, a respiration apparatus was designed in the Nutrition Laboratory, by means of which, without gas analysis, the oxygen consumption could be read directly from the contraction in the volume of a spirometer bell, and the carbon-dioxide production could be obtained by weighing certain bottles. This apparatus, while designed to be portable, proved rather cumbersome and, to fill urgent clinical needs for a strictly portable type, the original form of the portable respiration apparatus has been somewhat modified, being reduced in weight, provided with support and stand, and all parts adjusted so as to be more or less collapsible and thus occupy minimum space and facilitate transportation. With this apparatus the oxygen consumption of patients may be studied in the customary 10 to 15 minute periods with an accuracy fully equal to other standard methods of studying respiratory exchange. A simple method of timing the readings of the position of the spirometer bell eliminates the use of stopwatches. To compare the metabolism as measured on the new portable apparatus with that measured on the old, three series of tests were made on two different subjects with widely varying basal oxygen requirements, and the comparison showed a most satisfactory agreement between the two forms of apparatus.

(3) Carbon-dioxid content of barn air. Mary F. Hendry and Alice Johnson. Journ. Agric. Research, vol. 20, p. 405 (1920).

The construction of a large respiration chamber in the dairy barn of the Agricultural Experiment Station at Durham, New Hampshire, led to an investigation of the carbon-dioxide content of the air and its probable influence upon respiration experiments in case such air should inadvertently leak into the chamber. A series of analyses extending over all hours of the day and night showed a percentage of carbon dioxide ranging between 0.089 and 0.228. It is clear that there is a large percentage of carbon dioxide in the air of this modern barn, but its presence has had no apparent influence upon the health of the animals during the two decades that the building has been occupied. This fact is not without significance in the question of the ventilation of rooms occupied by humans.

(4) Tables, factors, and formulas for computing respiratory exchange and biological transformations of energy. Thorne M. Carpenter. Carnegie Inst. Wash. Pub. No. 303 (1921).

This publication is a compilation of tables, factors, and formulas which have been found to be of service in the calculation of results from data obtained with the various forms of respiration apparatus used with men and animals. A description of the tables is followed by a group of tables useful in the reduction to 0° C. dry and 760 mm. mercury-pressure of gas-volumes, either partially saturated with water-vapor as in a chamber, or completely saturated as is expired air collected in a spirometer. The various reliable factors and formulas for obtaining body-surface of man are given, followed by the standards (tables and formulas) for predicting the basal heat-production per 24 hours of all ages of both sexes, available up to the time of publication (Harris and Benedict, Benedict and collaborators, Aub and Du Bois, and Dreyer). The compilation concludes with a series of tables giving the factors for converting various units of work, energy, and measures into one another.

(5) The variation and the statistical constants of basal metabolism in men. J. Arthur Harris and F. G. Benedict. Journ. Biol. Chem., vol. 46, p. 257 (1921).

In all special investigations in human calorimetry some standard constant measuring the metabolism of the normal individual must be used as a basis of comparison. The selection of this constant presents a problem of some difficulty, as consideration should be given to the physiological conditions under which the measurements were made, the unit in which the caloric output shall be expressed, and the method by which the statistical constants for the standard series shall be obtained. It may be reasonably assumed that the results of the several periods of measurement on a given day stand in the relation of duplicate, triplicate, etc., analyses. The special purpose of this paper has been to investigate the variability in the basal metabolism of the normal individual and the method of determining a population mean from a series of individual constants. The average of daily periods of observation for individual men who have been studied from 20 to 53 days shows that the variability is measured by coefficients of variation of about 4 per cent of the average metabolism. The correlations between range of observations and variations in metabolism are greater for narrow ranges of observation than for the longer ranges, thus indicating that the greater part of the physiological variations in metabolism will be realized in relatively short periods of time. It is evident, therefore, that the metabolism of the normal subject is not constant, even with practically constant body-mass, but is to some extent in a state of flux. The results of this study also show that the population constant derived from individual means is less modified by weighting than that deduced from the individual minima. Probably weighting with the square root of the number of days rather than with the number of days would be the course recommended by most statisticians.

(6) The quantitative measurement of static control in standing. W. R. Miles. Am. Journ. Physiol., vol. 55, p. 309 (1921).

An abstract published in the Proceedings of the American Physiological Society, describing the static-control recorder, together with some results obtained by its use.

(7) The energy requirements of girls from 12 to 17 years of age. Francis G. Benedict and Mary F. Hendry. Boston Med. and Surg. Journ., vol. 184, pp. 217, 257, 282, 297, and 329 (1921).

Almost no evidence has hitherto been available regarding the energy requirements of girls of 12 to 17 years of age. With the cooperation of the Massachusetts Girl Scouts, nine groups of girls, usually 12 in a group, were studied on different nights inside of a large respiration chamber at the Nutrition Laboratory. The pulse-rate, insensible perspiration, and particularly the carbon-dioxide production throughout the entire night were determined frequently in 30-minute periods. The minimum values found throughout any given night have been taken as the basal requirement. This varies considerably in the different groups, although the total heat-production of the average girl remains strikingly uniform, irrespective of age or weight. Since the older girls are heavier than the younger ones, it is clear that the heat-production per unit of mass, i. e., per kilogram, is greater with the younger girls. The average, minimum, resting pulse-rate per minute of these girls from 12 to 17 years of age was found to be 81 at 12 years, 77 at 13 years, 77 at 14 years, 83 at 15 years, 71 at 16 years, and 74 at 17 years. The insensible perspiration per kilogram of body-weight per hour was 0.72 gram at 13 years, 0.71 gram at 14 years, and 0.77 gram at 15 years. The respiratory quotients of these groups of girls, about 7 to 8 hours after a light meal, were 0.81, 0.81, 0.78, and 0.79. The caloric requirement during 10 hours of "bed rest" was, on the average, 55.0 calories per individual per hour. The average 24-hour basal heat-production was 1,250 calories per individual, irrespective of age. The heat-production per kilogram of body-weight per 24 hours decreases regularly with increasing age, from 29.9 calories at 12 years 2 months to 21.7 calories at 17 years. The curve indicating the general metabolic trend is throughout its entire length materially below the few scattered observations of earlier writers. The heat-production per square meter of body-surface per 24 hours likewise decreases, but not so regularly, with increasing age, ranging from 928 calories at 14 years to 745 calories at 16 years. The metabolism of groups of young girls can be predicted from the general curve indicating the heat-production per kilogram of body-weight referred to age to within an average error of ±3.1 per cent. The prediction for the heat-production per unit of body-weight is somewhat better than that per unit of surface-area. The curves representing the heat-production per kilogram of body-weight referred to weight and per square meter of body-surface referred to weight for these groups of girls from 12 to 17 years of age blend with remarkable uniformity with similar curves based upon the measurement of a large number of normal girls from birth to 12 years of age. No influence of puberty or the prepubescent stage is clearly proved in any of the results.

(8) The basal metabolism of girls 12 to 17 years of age. Francis G. Benedict, Mary F. Hendry, and Marion L. Baker. Proc. Nat. Acad. Sci., vol. 7, p. 10 (1921).

An abbreviated presentation of the material in the foregoing article.

(9) The energy content of extra foods. (Sandwiches.) Cornelia Golay Benedict and F. G. Benedict. Boston Med. and Surg. Journ., vol. 184, p. 436 (1921).

This paper is a continuation of the first two communications on the subject of the energy-content of "extra foods." It presents the results secured with the ready-prepared sandwiches which may be obtained at the ordinary lunch-counter and drug-store. Although the prices during the period of observation (the spring of 1920) were somewhat higher than at present, it would seem that the Frankfurt sandwich at 5 cents was a most economical source of energy. On the other hand, the sliced-chicken sandwiches, frequently sold for 25 to 35 cents, represented an actual cost to the consumer of sliced chicken corresponding to approximately $5 or $7 a pound. The important rôle of sandwiches in the lunch or supplementary meal as affecting obesity, on the one hand, and on the other hand as a legitimate factor in any of the three meals of the day, is emphasized. The special purpose of these papers has been to point out that very considerable energy is obtained in these extra foods, i. e., candies, soda-fountain products, doughnuts, and sandwiches. Their influence in cases of obesity is obvious.

(10) The surface temperature of the elephant, rhinoceros, and hippopotamus. Francis G. Benedict, Edward L. Fox, and Marion L. Baker. Am. Journ. Physiol., vol. 56, p. 464 (1921).

Primarily for purposes of comparison with surface temperatures obtained on nude humans, measurements were made of the skin-temperature of a group of large, captive, hairless animals, namely, two elephants, a rhinoceros, and a hippopotamus, which had for years been subjected to the same routine of life in the New York Zoological Park. The average environmental temperature was 19.5° C. With the two elephants the average temperature of the skin was 25.5° C. Very pronounced temperature gradients were noted on various parts of the ears and extraordinary temperature differences were found at the tips of the right and left ears, both on the front and back of the ears and on different days. With the rhinoceros the average skin-temperature was 26.2° C., while in the semi-inclosed places, such as the groin and axilla and between the folds of the skin temperatures as high as 33.4° C. were found. The hippopotamus, by reason of its moist skin and amphibious nature, has a very widely varying skin-temperature. The skin is considerably colder on the back than on the belly. A rough average value shows the skin-temperature of the hippopotamus is not far from 25° C. All these animals, therefore, may be said in general to have the same skin-temperature, averaging about 25.5° C., or about 6 degrees above the environmental temperature.

(11) The measurement and standards of basal metabolism. Francis G. Benedict. Journ. Am. Med. Assoc., vol. 77, p. 247 (1921).

At a largely attended symposium on basal metabolism in clinical medicine during the Seventy-Second Annual Session of the American Medical Association at Boston in June 1921, occasion was taken to point out certain experiences of the Nutrition Laboratory in the measurement of basal metabolism and in the application of standards. The newest technique, with certain modifications, particularly as to testing, was presented. Stress was laid upon the difficulty of interpreting results and the standards for comparison, with special emphasis upon the normal variations from standard and particularly the influence of undernutrition. Practitioners were cautioned to familiarize themselves thoroughly with the fundamentals of gaseous metabolism and its significance, for the interpretation of results in gaseous metabolism measurements now far exceeds in complexity the actual laboratory technique.

(12) A pursuitmeter. W. R. Miles. Journ. Exp. Psychol., vol. 4, p. 77 (1921).

This paper describes a new apparatus for measuring the adequacy of eye-hand coordination which is probably one of the most important forms of human behavior to measure in connection with nutritional factors, fatigue, industrial conditions, and the like. The subject under test observes a wattmeter with zero center scale, and by the manipulation of a rheostat tries to maintain continually a balance between two opposing electrical circuits. The task is fairly uniform in nature, but so varied as to the direction, amplitude, rapidity of fluctuations, and rate of change in the current strength of one circuit as to require constant attention from the reactor. The "disturber mechanism" can be regulated to provide tasks of varying difficulty. The errors of compensation are integrated in two meters, from which the score may be directly read at the end of a test. Obviously the score combines both quickness and accuracy, and the smaller the meter-reading the better the performance. Test results with children and adults may be directly compared. The use of the apparatus is illustrated by some data on the influence of small amounts of alcohol.

(13) A pursuitmeter. W. R. Miles. Psychol. Bull., vol. 18, p. 102 (1920).

An abstract of the above-mentioned paper, published in the Proceedings of the American Psychological Association.

DEPARTMENT OF TERRESTRIAL MAGNETISM.[1]

LOUIS A. BAUER, DIRECTOR.

GENERAL SUMMARY.

INTRODUCTORY REMARKS.

The notable disturbances of the Earth's magnetism, brilliant polar-light displays, and severe earth-currents of May 13 to 16, 1921, which accompanied the remarkable sun-spot activity at the time, drew renewed attention to the relationships between these four classes of natural phenomena. The earth-currents generated within the Earth during the period of disturbances were of such a nature and magnitude as to cause on several days unusually serious interruption of telegraphic transmission, and disturbance of various other electric installations. In consequence, further information as to the precise causes and modes of action of disturbances in the Earth's magnetic and electric conditions is being zealously sought, both on theoretical and on purely practical grounds.

Telegraph companies have requested observers of sun-spots to keep them informed of notable solar phenomena in the hope that they might take whatever advance steps repeated experiences would show practicable for the prevention of serious interruptions from this source in telegraphic transmission. So, likewise, these organizations and interested persons are soliciting information regarding disturbances of the electric currents continually flowing in the Earth's crust and regarding deflections of the compass needle and the Earth's magnetism in general. Requests for such information are quite general. Thus, for example, the Telegraphs Branch of the Commonwealth Postal Department of Western Australia has requested of our observer-in-charge at the Watheroo Magnetic Observatory that he keep it informed of any abnormal magnetic conditions.

The Earth's magnetic changes are being continually recorded at about 50 stations, which, unfortunately, are not distributed over the Earth with the desired uniformity; the great majority are in Europe and only about 20 per cent are located in the Southern Hemisphere. But matters are still worse as regards earth-currents, since they are continuously recorded at less than 10 per cent of the total number of magnetic observatories. On the North American continent, Hawaii and Porto Rico, there are in operation 7 magnetic observatories, but at none of these, owing to various reasons, are there installations for earth-current observations. Accordingly, desired specific information can not at present be supplied to our telegraph companies and those interested in electric disturbances.

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[1] Address, Thirty-sixth Street and Broad Branch Road, Washington, D. C.

Now that the general magnetic survey of the ocean areas and unexplored regions, assigned to the Department of Terrestrial Magnetism as one of its initial great tasks, is coming to a conclusion as regards its first main purpose, efforts are being made to assist in meeting the needs referred to in previous paragraphs. Among the problems specifically mentioned in the plan[1] of work of the Department was that relating to observations of the manifold variations in the magnetic and electric conditions of the Earth, inclusive of its atmosphere, and their correlations with solar and allied phenomena. To this end a magnetic observatory was built at Watheroo, Western Australia, about 120 miles north of Perth, where, since January 1, 1919, continuous observations of the Earth's magnetic changes have been recorded by photographic means; these observations will be supplemented in the near future by others pertaining to atmospheric electricity and earth-currents.

The location of the Watheroo Magnetic Observatory is almost diametrically opposite to that of the magnetic observatory of the United States Coast and Geodetic Survey at Cheltenham, Maryland. The comparison of the magnetic variations and disturbances as recorded at the two stations on opposite sides of the Earth is proving of exceptional interest. During the period May 13 to 16, 1921, there were observed at the Watheroo Magnetic Observatory in the Southern Hemisphere, magnetic disturbances, polar lights (aurora australis), and earth-currents corresponding to those observed in the Northern Hemisphere, as for example, in the United States.

The second magnetic observatory of the Department, located at Huancayo, Peru, at an altitude of about 11,000 feet and about 125 miles east of Lima, is now nearing completion; it is hoped that the magnetic observations may be begun before the end of the year, and that electric observations may be undertaken some time in 1922. In addition, it is hoped that arrangements may soon be made for systematic observations pertaining to atmospheric electricity and earth-currents at other suitable stations in regions for which data are much needed. Among especially desirable regions at present may be mentioned: Northern part of North America, United States, Mid-Pacific Ocean, and South Atlantic Ocean or Africa.

Various studies concerning the relationships between solar activity and the Earth's magnetic and electric phenomena are in progress. These studies show once more the complexities of the relations. It is not possible always to correlate the intensity of sun-spot activity definitely with magnetic effects. There are well-established cases of severe magnetic storms during complete absences of visual evidence of sun-spots; at times these storms may be related to some other solar phenomenon, such as prominences. The central position of the sun-spots of May 14 to 15 last, the character of their formation, and the time of the year, were favorable to the production of a magnetic disturbance on the Earth. In these studies various measures of solar activity are being tried out (see pp. 348–351).

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[1] Published in the Year Book of the Carnegie Institution of Washington for 1903, pp. 203–212.

Besides the relationships referred to in the first paragraph, it has been found that there is another geophysical phenomenon—atmospheric electricity—between which and solar activity a definite relationship exists, as described on page 350. The electric potential gradient of the air, on days free from disturbing influences, and also the range of its daily fluctuation, are found to increase, in general, with increased solar activity.

It further results from our preliminary studies that the Earth and probably the other planets are apparently sending out into space or returning, by a sort of reflex action, a portion of the electrified particles continually received from the Sun; as a result the Earth exerts, apparently, upon sun-spot activity, a small but observable electric effect of a double-wave character during the year. On the average, the maximum Earth-effects occur at the times of the year, near the equinoctial months, when magnetic disturbances and polar lights are most frequent, and the minimum Earth-effects occur near the solstitial months, when magnetic disturbances and polar lights are least frequent (see p. 351). It would appear more and more that besides those of gravitation, there are other bonds of union—electrical in their nature—between the Earth, the sister planets, and our parent Sun, by means of which the cosmic forces responsible for electric and magnetic effects, such as we observe, are conveyed.

OCEAN WORK.

The *Carnegie's* present world cruise (No. VI) of total length 64,044 nautical miles, begun at Washington on October 9, 1919, was completed at the same port on November 10, 1921. The success attendant upon this cruise, referred to in the report of 1920, has continued throughout the current year. The commander, J. P. Ault, and his able staff, deserve much credit for the successful management of the vessel and for their persistence under difficulties as well as for the quality and quantity of the observational data obtained. The prompt transmittal of the observed data to the office at Washington has made it possible to continue supplying promptly to the leading hydrographic establishments the data required for correction of the magnetic charts used by mariners. The steady improvement in these charts since 1905, when our ocean magnetic work was begun, is very gratifying (see table 1, p. 342).

The present cruise up to the arrival of the *Carnegie* at Washington, November 10, 1921, is shown delineated on the accompanying map.

The ports and dates of arrival indicate, in a general way, the portion of the cruise from October 1920 to its conclusion: Lyttelton, New Zealand, October 21, 1920; Papeete, Tahiti, December 23, 1920; Fanning Island, January 14, 1921; Laysan Island was passed at a distance less than one mile on January 25; San Francisco, February 19; Honolulu, April 12; stops of a few hours' duration for obtaining some food supplies were made at Penrhyn Island, June 12, and at Manihiki Island on June 15; Pago Pago, Tutuila, June 20; Apia, Samoa, June 29; a brief stop was made at Rarotonga, August 15, in order to land the ship's surgeon, who was suffering from an infected arm; Balboa, Canal Zone, October 7; Washington, November 10, 1921. The Director joined the *Carnegie* at Balboa on October 12 and continued with her up to her arrival at Washington. For further account of the cruise and the work reference must be made to pages 317-323.

The aggregate length of the *Carnegie's* cruises, 1909–1921, is 253,220 nautical miles, or 291,595 statute miles, which. combined with the cruises of the first vessel (the chartered *Galilee*, 1905–1908, 63,834 nautical miles), gives a total of our ocean cruises, August 1905 to November 1921, of 317,054 nautical miles, or 365,103 statute miles, which is nearly 15 times the Earth's circumference. Counting out the times when the vessel was not in commission, on account of repairs and of the Great War, more than a complete passage around the Earth has been made for each 12 months of operation.

Besides the magnetic work, the work in atmospheric electricity has been regularly continued and important results have been obtained, especially as pertains to the electric potential gradient of the atmosphere (see pp. 354-356. The additional observations made aboard the *Carnegie* relate to atmospheric refraction, meteorology, hydrography, and geography. Rock specimens have also been collected at ports of call in cooperation with the Geophysical Laboratory for facilitating Dr. Washington's investigations.

LAND MAGNETIC-SURVEY WORK AND SPECIAL EXPEDITIONS.

It has not yet been possible, because of expense and lack of personnel, to resume the land work with pre-war intensiveness. It would seem necessary to place the *Carnegie* temporarily out of commission in order that the requisite funds and observers for the land work may become available.

Mr. Frederick Brown carried out field work continuously throughout the year; the general regions of the work were Eastern Africa and Madagascar. A fairly detailed magnetic survey of Madagascar has been completed, and Mr. Brown further obtained valuable data regarding the secular changes in the Earth's magnetism. (For further account of his work, see pp. 323-325.)

In May 1921, Dr. H. M. W. Edmonds and Observer D. G. Coleman were sent to Apia, Samoa, where they arrived about the middle of June.

Starting out from Apia as a base-station, Mr. Coleman proceeded, under Dr. Edmonds's direction, to make magnetic observations on various islands in the Pacific Ocean. Mr. Coleman was especially charged with the reoccupation of certain stations at which Department observers had made observations some years ago in order that he might obtain the requisite data for determining the changes—known as secular changes—which the Earth's magnetic state has undergone since the dates of the earlier observations (see p. 326).

At all ports of call of the *Carnegie* as planned, Captain Ault's party has made valuable magnetic observations.

The Department has cooperated with two polar expeditions—the "*Maud* Expedition," under the leadership of Captain Roald Amundsen, and the "Baffin Land Expedition," under the command of Dr. Donald B. MacMillan. Important magnetic data have been obtained already from both expeditions (see pp. 325-326 and 327).

OBSERVATORY WORK.

Some general statements concerning the present observatory work have already been made in the "Introductory Remarks." The work performed during the year may be summarized as follows:

Watheroo Magnetic Observatory, Western Australia.—Captain E. Kidson was observer-in-charge during the period November 1, 1920, to January 31, 1921, when he resigned, to our great regret, in order to accept the appointment of supervising meteorologist in the Central Weather Bureau at Melbourne. He was succeeded by Mr. W. C. Parkinson, who with the assistance of Assistant Observer J. Shearer has successfully continued the activities of the observatory. Dr. G. R. Wait left San Francisco in September for the Watheroo Magnetic Observatory to install there the initial units of what is ultimately to be a comprehensive equipment for atmospheric-electric work. This equipment was constructed in the Department's instrument shop. Dr. Wait will take full charge of the observatory work at the end of 1921 to relieve Mr. Parkinson. Owing to circumstances arising from the war it was necessary, unfortunately, for Mr. Parkinson to remain continuously on duty at the isolated observatory site for a period of about five years. High praise must be accorded him for his unflagging devotion and zeal and for the conscientious and painstaking manner in which he has performed his duties. (For an account of the observatory's work during the year, see pp. 328-329).

Huancayo Magnetic Observatory, Peru.—Dr. H. M. W. Edmonds continued in charge of the construction of this observatory until March 31, 1921, when he was relieved and assigned to the Pacific Ocean work described below and on page 326. He was succeeded by Mr. W. F. Wallis, who is an experienced magnetician and an architect. It will be seen from pages 329–330 that Mr. Wallis has made excellent progress in the completion of the various buildings. The photographic instruments for the magnetic work were installed and it was expected that continuous magnetic observations would be begun the latter part of the year. (For details and account of some preliminary observations, see page 330.)

Apia Observatory, Samoa.—After various negotiations, the New Zealand Government decided to continue at its expense the magnetic and seismic work of the Apia Observatory, which was established in 1902 under the auspices of the Göttingen Gesellschaft der Wissenschaften and of the German Government. The activities of the observatory were maintained in full throughout the Great War under the direction of the German observer-in-charge, Dr. G. Angenheister, who returned to his native country in July. Mr. C. J. Westland, of New Zealand, is the present observer-in-charge. The Apia Observatory was originally established with the view of cooperation with the German Antarctic Expedition of 1902–1904; the German Government continued it later and thus cooperated with the Department of Terrestrial Magnetism in the Pacific Ocean work. The magnetic data obtained at the Apia Observatory are required for the satisfactory reduction of our ocean magnetic work. Similarly, continuous observations in atmospheric electricity at the Apia Observatory are desirable in connection with the reduction of our ocean electric work. Unfortunately, however, the New Zealand Government was unable to provide for the expense of maintenance of the atmospheric-electric work after Dr. Angenheister's departure. In order to maintain the continuity of this work the Department, in cooperation with the New Zealand Government, has stationed Dr. H. M. W. Edmonds at Apia for the purpose of continuing, as well as possible with the available means, the atmospheric-electric observations, pending other arrangements. The New Zealand Government has courteously furnished Dr. Edmonds with living quarters. As stated on page 326, Dr. Edmonds, while stationed at Apia, also has charge of the Department's magnetic-survey work of the Pacific Islands.

MacMillan Baffin Land Expedition.—In cooperation with this expedition, instruments, plans, and directions were furnished for temporary observatory work in the polar regions, 1921 to 1922, and instruction was given to the observers. The observations to be undertaken, if conditions permit, will pertain to terrestrial magnetism, atmospheric electricity, and polar lights (see pp. 327 and 334).

Washington, District of Columbia.—Numerous comparisons and standardizations of magnetic instruments have been made in the course of the year in the Standardizing Magnetic Observatory. The most interesting of these instrumental comparisons have been those between the Department's standard magnetometer and its sine galvanometer, with which the horizontal component of the intensity of the Earth's magnetic field is measured by electric means. Our standard magnetometer has been compared at various times during the past 15 years with magnetometers in use at most of the magnetic observatories and in most of the magnetic services throughout the world. The comparisons made between it and the sine galvanometer have shown that the adopted standard for horizontal intensity may be regarded as an absolute one well within theoretical and practical requirements (see pp. 338 and 346).

For an account of the atmospheric-electric work in the deck observatory, see page 333

Miscellaneous.—Various plans were prepared for the structural and observational work at the observatories; requisite instruments were also designed and constructed in the instrument shop. Considerable time was devoted to the development of observatory buildings, instruments, and equipment for standardized practice, particularly as pertains to atmospheric-electric methods and records. (See pp. 333 and 337.)

RESEARCH WORK IN WASHINGTON.

TERRESTRIAL MAGNETISM.

The manuscript was completed for Volume IV of "Researches of the Department of Terrestrial Magnetism," bearing the title "Land Magnetic Observations 1914–1920, and Special Reports" by L. A. Bauer, J. A. Fleming, H. W. Fisk, W. J. Peters, and S. J. Barnett; this volume is now passing through the press. The special reports are as follows:

Construction of Non-Magnetic Experiment Building of the Department of Terrestrial Magnetism, by J. A. Fleming.
Dip-Needle Errors Arising from Minute Pivot-Defects, by H. W. Fisk.
A Sine Galvanometer for Determining in Absolute Measure the Horizontal Intensity of the Earth's Magnetic Field, by S. J. Barnett.
Results of Comparisons of Magnetic Standards 1915–1921, by J. A. Fleming.

When Volume IV has been issued, the observational data resulting from our land magnetic surveys from 1905 to 1920 inclusive will have appeared in print. The ocean magnetic data, 1905–1916, were published in Volume III, and preliminary results for the period 1917–1921 have been published promptly in the various issues of the journal *Terrestrial Magnetism and Atmospheric Electricity.* In addition and upon request, magnetic-survey data, not already in print, were furnished to interested institutions and investigators.

Preparatory to the reduction to common epoch of the accumulated data and the construction of new world magnetic charts, a variety of investigations were undertaken; some of these have been completed and others are in progress. Thus, for example, it is of importance to have some idea at least, before making a new analysis of the Earth's magnetic field, as to what extent the magnetic forces observed on the Earth's surface may be caused, possibly, by a system of electric currents passing perpendicularly through the Earth's surface. Students of terrestrial magnetism regard this as one of the outstanding questions of the present time, the definite solution of which has an important bearing on theories of some of the Earth's magnetic and electric phenomena. A preliminary investigation on the basis of the most complete data available appears to lead to some positive results and to indicate that possibly 2 to 3 per cent of the Earth's total magnetic field is caused by a system of vertical currents of the kind described (see p. 348). In the planning of the various cruises of the *Galilee* and of the *Carnegie*, special consideration was given to obtaining comprehensive tests of this interesting question in various parts of the Earth.

Some further results of these preparatory studies were previously mentioned under "Introductory Remarks." For fuller accounts of these studies see pages 332-333 and 347-351.

MAGNETISM IN GENERAL.

Improvements in appliances and methods have resulted in obtaining greater precision in the experiments on magnetization by rotation conducted by Dr. S. J. Barnett in the Department's non-magnetic experiment building, the completion of which was reported upon last year. The results of the two independent methods (the method of electromagnetic induction and the magnetometer method) have been brought into better agreement than they were before. Dr. Barnett states (see p. 341) that the present results confirm the result first obtained by the method of electromagnetic induction, namely: Either negative magnetons with a value of the ratio of angular momentum to magnetic moment, different from that ordinarily accepted for electron rings, are responsible for magnetism, or else positive electrons or magnetons are also involved. The experiments are being continued. It has not yet been possible to go further with the experiments on rotation by magnetization.

For further details reference may be made to Dr. Barnett's report on pages 340-341 and to the abstracts of his papers and communications to scientific societies on pages 345-346.

TERRESTRIAL ELECTRICITY.

The section of Terrestrial Electricity has continued under the charge of Dr. S. J. Mauchly, whose report on pages 333-335 may be consulted as to details.

The principal activities of the section may be summarized as follows: Reduction of atmospheric-electric observations made aboard the *Carnegie* and at Washington in the temporary observatory on the deck of the main laboratory of the Department; studies and improvements of observational methods; designs of instruments for the atmospheric-electric work at the Department's observatories and for the MacMillan Baffin Land Expedition; study of methods and equipment for polar-light observations; investigations based on the accumulated results in atmospheric electricity.

A statement of some of the important results derived from electric observations made aboard the *Carnegie*, which have a significant bearing upon theories of atmospheric electricity, will be found on pages 354-356.

Through its extensive ocean work the Department is not only obtaining the chief data pertaining to the geographic distribution of the atmospheric-electric elements, but is also enabled to contribute important data respecting the diurnal and annual variations of these elements.

It is still true that the Department's station at Washington is the only one in the United States where continuous records of the changes in the electric condition of the atmosphere are being obtained. These records are being consulted by various outside investigators, especially by those who are making studies of the atmospheric disturbances encountered in wireless transmission.

STANDARDIZATION AND INSTRUMENT WORK.

As in previous years, the investigations and work under this head have been conducted in the Magnetic Survey Division, in charge of Mr. J. A. Fleming, to whose report on pages 337-340 reference may be made concerning details.

Reference has already been made on page 312 respecting interesting results obtained from the comparisons of instruments of various types, these results having important bearings upon methods of observation. (See also p. 337.)

The construction of sine galvanometer No. 1, as designed by Dr. Barnett, for determining in absolute measure the horizontal intensity of the Earth's magnetic field, was completed. It has already been stated on page 313 that comparisons made under Mr. Fleming's direction between the sine galvanometer and the Department's standard magnetometer showed a very satisfactory agreement.

It will be seen from Mr. Fleming's report (pp. 337-340) that an unusual amount of construction work in the instrument shop was completed during the year. Much of this work was in connection with the designs of instruments of high grade for the varied work of the Department at Washington, in the field, and at its observatories, or in connection with special expeditions.

Owing to the heavy pressure upon our shop for the appliances required by the Department in its own work and because of the continued scarcity of skilled instrument-makers and high costs of construction, it has not been possible to meet in any respect the requests we continue to receive from foreign institutions for instruments of our design.

MISCELLANEOUS MATTERS.

Site at Washington.—In the early part of 1921 an additional strip of land of about 75,000 square feet was purchased in order to protect the work performed in the Experiment Building and in the Standardizing Observatory from possible disturbing influences. The total area of the site at Washington is at present about 8¾ acres, and it is now bounded on all sides by streets, already constructed or contemplated.

American Section of Terrestrial Magnetism and Electricity.—The following papers were presented by members of the Department at the annual meeting on April 18, 1921, before the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union:

S. J. Barnett: A sine galvanometer for determining in absolute measure the horizontal intensity of the Earth's magnetic field.
L. A. Bauer: On measures of the Earth's magnetic and electric activity and correlation with solar activity.
S. J. Mauchly: Recent results derived from the diurnal-variation observations of the atmospheric-electric potential gradient aboard the *Carnegie*.

The officers of the section, as in the case of last year, are: Louis A. Bauer, chairman (also vice-chairman of the American Geophysical Union); W. F. G. Swann, vice-chairman, and J. A. Fleming, secretary.

Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union.—The Director has continued throughout the year his duties as secretary of the International Section and as director of the central bureau. Arrangements for the triennial meeting of the Section and of the Union at Rome in April 1922 are under way.

National Research Council.—Various duties have been performed by Messrs. Barnett, Bauer, Fleming, Mauchly, and Peters, in connection with committees of the Council.

DETAILS OF OBSERVATIONAL WORK.

OCEAN-SURVEY WORK.[1]

The *Carnegie* continued the ocean-survey work throughout the year. On November 1, 1920, she was at Lyttelton, New Zealand. The series of comparisons between the standard instruments of the Christchurch Observatory and those of the *Carnegie* were satisfactorily completed early in November; Mr. H. F. Skey, director of the Observatory, extended every courtesy and facility for this work and took an active part in the observations. The *Carnegie* was towed out to sea November 19 and proceeded under her own power until after clearing Banks Peninsula, when all sails were set. For 3 days the wind blew from the north, then shifted to the west and remained westerly for 4 days. The 180th meridian of longitude was crossed on November 22, and the date November 22 was repeated.

No heavy storms were met, but moderate gales blew on November 22, November 27, December 1, and December 5. From December 1 to December 10 the wind blew steadily from the northwest, driving the vessel about 600 miles east of her course. On December 14, on entering the southeast trade-wind, course was set for Papeete, which was reached November 23.

The total distance sailed from Port Lyttelton to Papeete was 4,262 miles, which gives a daily average of 122 miles for the 35 days at sea. Magnetic observations were obtained at 54 stations for declination and at 33 stations for inclination and horizontal intensity. Complete determinations of the 5 atmospheric-electric elements (potential gradient, conductivity, ionic numbers, penetrating radiation, and radioactive content) were made on 9 days; 4 elements were observed on 13 days; and three 24-hour series of diurnal-variation observations for the first three elements named were made.

Shore observations to obtain secular-variation data were made at the Department's station of 1916 at Point Fareute. Some special work was also done in connection with the atmospheric-electric instruments.

The *Carnegie* left Papeete Harbor on the afternoon of January 3, 1921, in the midst of a heavy tropical rain squall. Fortunately, the wind held more from the east than from the north during the entire run from Papeete, so that Fanning Island was sighted at 10 o'clock on the morning of January 14 from a good bearing, after being hove to 60 miles east of the island during the previous night. The vessel arrived off Whaler's Anchorage at 1^h 25^m p. m., and after tacking back and forth for 2½ hours, during which time cablegrams were despatched, departure was taken for San Francisco. The old *Galilee* station is no longer available on account of the extension of buildings and electric wiring; observations could not be made ashore, owing to the necessity of sailing that evening.

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[1] From Commander J. P. Ault's reports.

As the vessel was now leaking more than usual, it was considered advisable to proceed to San Francisco to dock for examination. The course was kept somewhat eastward of the one planned, so that it passed through the western Hawaiian Islands at Laysan Island instead of beyond the Midway Islands. From Fanning Island to Laysan there was no calm belt and no evidence of a proper northeast tradewind. The easterly wind blowing at Fanning Island continued until after passing Laysan Island, often blowing from south of east. Laysan Island was passed at a distance of 1 mile on January 25. The position of the landing-place near the group of buildings, from the observations made on board the *Carnegie*, is: latitude, 25° 46.′1 north; longitude, 171° 42.′7 west of Greenwich. This position depends upon a latitude observation on Venus simultaneous with a longitude observation on the Sun in the afternoon 2⅓ hours before passing the island, and upon latitude and longitude observations from stars 3 hours later, taken 10 minutes after the last bearing was obtained on the island, at a distance of about 1⅓ miles. There was no evidence of a northerly or southerly current, and only 0.1 knot per hour westerly set between the 2 observed positions. The longitude has been corrected for chronometer error determined after arrival at San Francisco. The position as given on the chart is 25° 42.′2 north, 171° 44.′1 west for the lighthouse, which should be near the landing-place as above. This shows the island to be 3.9 miles north of its charted position and 1.3 miles east. Soundings of 8 and 8½ fathoms were obtained 1 mile off the southern end of the island, where, also, numerous dark patches were noticed which seemed to indicate shallower water.

On January 28, in latitude 32° north, a northwesterly gale began which continued for 4 days and prevented making the desired northing. From February 1 to February 11 southerly winds and gales continued without interruption. Rough seas and consequent increase in leaking made it necessary to proceed under greatly reduced sail. Fine weather prevailed February 17, 18, and 19. A good landfall was made at 1 p. m., February 19, by bearings on Point Reyes and the Farallon Islands, and the anchorage in San Francisco Bay was reached at 10 o'clock the same evening.

Declination observations were made daily with the exception of two days. Unusually good weather was found near the California coast, so that declinations were obtained where previous cruises had failed to get them on account of clouds and fog.

The *Carnegie* arrived at San Francisco after 47.3 days at sea. The average daily run was 128.9 miles for the 6,099 miles traversed. Magnetic observations were obtained at 81 stations for declination and at 44 stations for inclination and horizontal intensity. Because of instrumental difficulties, the radioactive content was measured on 3 days only. The other four atmospheric-electric elements were observed on 21 days, and diurnal-variation observations were attempted on 6 days, on 3 of which weather conditions prevented a complete series.

At San Francisco the vessel was dry-docked, and such general repairs as found necessary on examination were made. Because of the short cruise planned before the return to Washington, when the vessel probably will have to be opened up for careful examination and possibly extensive repairs before going out again, it was decided to copper-paint instead of resheathing the hull. The electric generator was replaced by a 2-kilowatt generator, in order to make more adequate provision for the experimental work.

Advantage was taken of the delay occasioned by the repair work to obtain complete standardizations of the ship's magnetic instruments at a new station, Fort Scott; the old station on Goat Island was found no longer suitable. Complete intercomparisons between substandard magnetometer-inductor No. 26, which had been brought especially for this work from Washington by Mr. Fleming, and the ship's standard land-instruments were also made at Fort Scott. The results showed that the corrections for the ship's equipment had remained nearly constant.

Dr. J. C. Merriam, President of the Institution, made a personal inspection of the *Carnegie* on March 24.

The chief of the Magnetic Survey Division (Mr. Fleming), representing the Director, made an inspection of the vessel during February 24 to March 7, while she was in San Francisco, and took up various urgent matters with Captain Ault relating to instruments, equipment, and future work.

Upon the completion of the other shore work capacity determinations were made for the conductivity apparatus, the radioactive content apparatus, the ionic-content apparatus, and the penetrating-radiation apparatus.

The repair work and other business matters being completed, the *Carnegie* left the dock at 4 p. m. on March 28 and sailed direct for Honolulu. During the entire passage observing conditions were good and permitted declination observations twice every day, except on April 1, when cloudy weather prevented them. Winds were moderate to fresh and favorable all the way. As the Hawaiian Islands were approached, the wind became quite strong and a very heavy current from the south was found in Kaiwi Channel, between Molokai and Oahu islands. The vessel arrived off Honolulu Harbor early on April 12 and was alongside the dock at $8^h 40^m$.

The distance traversed was 2,222 miles, giving an average of 151 miles per day for the 14.7 days of the trip. Magnetic observations were obtained at 27 stations for declination and at 14 stations for inclination and horizontal intensity. Atmospheric-electric observations of the five elements were carried out on 3 days and of all elements except the radioactive content on 7 other days; 24-hour series diurnal-variation observations were made on 3 days.

The marked changes and improvements in the methods, instruments, and equipment provided for ocean observations since the cruise of the *Galilee* 16 years ago are extremely gratifying. The *Galilee* made the passage from San Diego to Honolulu in 12 days during the year 1905, covering much the same region as the *Carnegie* covered this time. Thirteen stations were occupied then, as contrasted to 41 on the *Carnegie's* trip.

During the stay at Honolulu, a complete series was obtained of comparisons between the magnetic standards aboard the *Carnegie* and those at the Honolulu Magnetic Observatory of the United States Coast and Geodetic Survey. Additional capacity determinations were made for the ion counter, the radioactive apparatus, and the conductivity apparatus.

After completion of the comparisons at the Honolulu Magnetic Observatory, the *Carnegie* sailed on April 28, and upon rounding the island of Oahu ran into the northeast trade-wind, which held until parallel of 34° north latitude. Westerly and northerly winds generally prevailed as the vessel sailed eastward along this parallel. On May 13 the northeast trade-wind was picked up again and then a southeasterly course was steered until May 21, when it was changed to a southwesterly one direct for the Samoan Islands. The *Carnegie* entered the region of the "doldrums" on May 27 and left it on May 29 with a light southeast wind which continued with variable force all the way to Pago Pago, but grew quite strong two days before the port was reached.

On June 12 a stop of a few hours was made at Penrhyn Island, which is a typical coral atoll The brief visit ashore was a welcome relaxation and enabled the party to secure some coconuts and Rarotonga oranges. A stop of a few hours was also made at Manihiki Island on June 15, and fresh fish, eggs, and coconuts obtained.

The Manua Islands were sighted early on June 20, and by $6^h 20^m$ on the same evening the vessel was moored to the buoy in Pago Pago Harbor. After setting up the rigging and replenishing stores, the *Carnegie* left Pago Pago in the afternoon of June 28 and arrived off Apia the following morning. The total distance to Apia was 5,980 miles, which makes an average of 110.7 miles per day for the 54 days of sailing.

Winds were usually quite favorable throughout the passage, though never very strong; no storms were encountered and observing conditions were excellent. Declination observations were made on every day but one, usually twice a day. The total number of stations was 96;

inclination and horizontal-intensity observations were made at 48 stations. On May 31 the vessel was swung for declination observations under fairly good conditions, the maximum rolling being 5° to starboard and 8° to port, and the ranges in the results were no larger than the indicated error of observation, 5′ in the collimator results and 9′ in the deflector.

After official calls on the American consul and on the governor, arrangements were made for the work to be undertaken at the Samoa Observatory. The comparison of standards at the Observatory with those of the *Carnegie* was begun on June 30, after consultation with Mr. C. J. Westland, at present in charge of the Observatory, and with the former director, Dr. Angenheister, who left Apia on July 2 to return to his native country. Plans regarding continuance of the work in atmospheric electricity and regarding the past work and methods were discussed with Dr. Angenheister and Mr. Westland. Upon cabled authority from the Office, and since some of the observatory apparatus was in poor condition, certain appliances for atmospheric-electric work were transferred from the ship to Dr. H. M. W. Edmonds for use at the Apia Observatory while he is stationed there (see p. 312). A magnetometer, typewriter, and other equipment were also left at the Observatory for Dr. Edmonds's use, as may be found necessary.

For facilitating the comparisons at the Apia Observatory, two new outside stations were established, as the outside pier heretofore used for intercomparison work was found to be constructed of magnetic material. All ship instruments were also standardized. With the cordial and effective cooperation of Mr. Westland and of Dr. Edmonds, the large amount of observational work was satisfactorily completed and the *Carnegie* sailed for the Canal Zone on July 25.

It was necessary to depart from the track originally planned in order to land Dr. Pemberton for medical treatment at Avarua, Rarotonga Island, and allow him to return home. The vessel left Rarotonga on August 15 and arrived at Balboa October 7. The *Carnegie* tracks of earlier cruises were crossed 12 times and the *Galilee* track of 1908 was crossed once. These intersections will yield important secular-variation data. A reversal of the usual currents was noted in the Gulf of Panama, the set being toward the south instead of to the north. Excellent results were obtained during the frequent observations of diurnal variation in atmospheric electricity. The average daily run was 123 miles for the 72 days between Apia and Balboa.

Secular-variation observations were made at Colon, and after drydocking at Balboa the *Carnegie* proceeded through the Canal and set sail on October 20 for Washington on the last passage of Cruise VI.

A favorable southeast wind enabled her to make excellent headway towards Windward Passage, through which she ran on October 25 and 26 in a calm. Gales, or strong winds, then prevailed to November 6, when Cape Henry was sighted early in the morning. At 11 a. m., November 6, the *Carnegie* put in at Old Point Comfort and about an hour later proceeded up Chesapeake Bay to "swing ship" the following day at the same place as in 1909. "Swing observations" were made for the magnetic elements on November 7, and the reduction factor for potential gradient was determined off Solomons Island the next day. The results of the "swing magnetic observations" verified the absence of any appreciable "deviation-corrections" at the observing places aboard the *Carnegie.* On November 9 the *Carnegie* left for Washington, came up the Potomac with engine running, and docked at Smith's wharf at 5^h 30^m p. m., November 10. The total distance at sea was 1,975 miles, which was made in 17 days at an average daily speed of 115 miles.

The Director joined the vessel at Balboa on October 12 for inspection of the work, and accompanied her on the return cruise to Washington. Mr. R. R. Mills returned to the United States from the Canal Zone to resume his university studies. Dr. F. A. Franke was assigned to the ship's personnel at Balboa to take the place made vacant because of the illness of Dr. Pemberton.

The engine has been run very satisfactorily on many occasions throughout Cruise VI.

The total number of declination stations obtained during the cruise from Port Lyttelton to Washington was 407, and the total number of horizontal-intensity and inclination stations was 222 for each element. The total distance covered was 29,384 nautical miles in 240 days at sea, making an average daily travel of 122 nautical miles. The average distribution of stations along the track of the cruise is very satisfactory, namely, one declination station for every 72 nautical miles and one horizontal-intensity and inclination station for every 133 nautical miles. In addition to the magnetic work, atmospheric-electric observations have been carried out regularly for 4 or 5 atmospheric-electric elements on each of 148 days, while diurnal-variation observations in atmospheric electricity were made on 27 days. In addition, pitch-and-roll records of ship's motion have been obtained frequently, and daily meteorological observations and various observations for determining geographic position have been made. Considerable time has been devoted to obtaining further data regarding performance of galvanometer and of earth-inductor on board ship, as shown by the inductor observations, using the string galvanometer and the marine d'Arsonval galvanometer on alternate days; the work with the string galvanometer is not yet altogether satisfactory. Rock specimens were collected at ports of call for Dr. H. S. Washington's investigations at the Geophysical Laboratory.

The ship's personnel has been as follows: J. P. Ault, chief of the Section of Ocean Work, in command; H. F. Johnston, magnetician, second in command; Russell Pemberton, surgeon; A. Thomson, H. R.

Grummann, and R. R. Mills (until October 12), observers; F. A. Franke, surgeon (from October 12); A. Erickson, first watch-officer; C. E. Leyer, engineer; L. Larsen, second watch-officer; N. C. Jörgensen, third watch-officer; 2 cooks; 1 mechanic; 8 seamen; 2 cabin-boys; in all, 23 men. In addition, the Director was aboard from Balboa to Washington, October 12 to November 10.

The continued success of the ocean-survey work has been made possible in no small measure by the privileges and many courtesies extended the *Carnegie* and her staff by governmental and harbor authorities, as well as by men of science, at every port of call.

Concerning the preliminary results of ocean magnetic observations on the *Carnegie* for Cruise VI from Lyttelton, New Zealand, to Washington, November 1920 to November 1921, see abstracts and tables on pages 342-345.

LAND-SURVEY WORK.

The demands upon personnel and funds, as referred to on page 310, have restricted the amount of land-survey work. An excellent series of observations at new and secular-variation stations has been obtained in Africa, and a fairly detailed magnetic-survey of Madagascar has been completed. Valuable magnetic data have also resulted from the land observations at ports of call of the *Carnegie* and on some of the islands of the Pacific Ocean by a special land party. In addition, some magnetic results have been obtained by cooperation with two polar expeditions.

AFRICA.

Mr. Frederick Brown, who began work in Africa in April 1919, had completed his work in Cameroun by the end of that year and was engaged throughout the greater part of 1920 in making a trans-continental trip across Angola, Rhodesia, and Mozambique. On August 4, 1920, he arrived at Feira on the eastern boundary of Northern Rhodesia and crossed over into Portuguese East Africa. Chinde was reached September 21, 1920. Mr. Brown proceeded thence down the coast about 150 miles to Beira, where plans were made for the work in Madagascar.

From March 14, 1920, the date of arrival at Lobito on the west coast of Angola, to October 1, the date of departure from Beira on the east coast of Portuguese East Africa, 54 stations had been occupied at an average rate of less than 4 days for each station, while a distance of nearly 3,200 miles had been traversed, making the average distance between the stations approximately 60 miles. About 1,800 miles had been covered on foot with carriers and about 400 miles by canoe. The average field-expense for each station was a little less than $20. Eleven of the 54 stations had been occupied previously by other observers of the Department; 4 of these were near the west coast, 5 were in central Africa, and 2 were near the east coast.

After the conclusion of the work in Africa in October 1920, Mr. Brown proceeded to Madagascar, going from Beira by way of Porto Amelia to Majunga on the northwest coast of the island, making use of the opportunity en route to secure observations at the 1909 station at Mozambique. He went directly from Majunga to the capital, Tananarive, where he was cordially received by the Governor-General and accorded every facility for carrying out the proposed program of work in the island. Instructions were telegraphed to the various administrators of the several districts to be traversed to cooperate as occasion required, with the result that there was scarcely any delay in prosecuting the work which occupied the following 8 months. An intercomparison of instruments was made at the Tananarive Observatory with the effective cooperation of Father Colin, S. J., the director. Because of excessive magnetic disturbances in the region about Tananarive, a large number of auxiliary stations was occupied, particularly along the route from Majunga to Tananarive. Elsewhere in the island there was less necessity for such multiplicity of stations.

Leaving Tananarive on November 25, Mr. Brown traveled southwestward with carriers along the high ridge in the east-central portion of the island as far as Betroka, whence he turned westward and followed the Onilahy River downward to the coast at Tulear. Leaving that point on January 9, 1921, for Fort Dauphin, he took a route along the coast, intending to follow the shore as far as Cap Sainte Marie. The region was poorly supplied with water and there was suffering among his men before he reached Androka; marching along the sea-sand was intolerable during the middle of the day. From Androka to Fort Dauphin conditions were not favorable, as there had been a three-year drought and famine conditions prevailed, making the question of food-supply for the men a serious one. Many carriers gave up from exhaustion; nevertheless, Mr. Brown reached Cap Sainte Marie on January 25, a point seldom visited by white men on account of the scarcity of water. The return northward could not be made by sea, as had been hoped, without an extended delay waiting for steamer service, the season of prevailing northeasterly winds and bad weather preventing the use of small sailing-craft or canoes. An overland route paralleling the eastern coast was therefore taken; Mr. Brown arrived once more in Tananarive on March 22. Setting out again on April 9 and proceeding northward with carriers, he followed the high plateau as far as Mandritsara, whence he turned eastward to the coast, following it to the northern extremity of the island at Diego Suarez. Here he joined a coastal steamer that was making the trip along the west coast. Stops of sufficient length to allow time for observations were made at Hellville and Ananalava. He remained with the steamer as far south as Ambohibe, about 200 km. north of Tulear, and traveled thence northward overland a distance of about 500 km. to

Maintirano, where he arranged to cover the remaining distance back to Majunga by sailing cutter, arriving there on June 28.

Ninety-four stations were occupied in Madagascar; 11 were more or less precise reoccupations of previous stations by the French Hydrographic Service or by Father Colin, and 11 were auxiliary stations established for testing for the existence of local disturbance or to secure a more favorable location after occupying a previous station in the same general region. The station at Majunga was occupied at the beginning of the work and again at the close. Of the 6,000 kilometers' travel necessary to reach these stations, all but about 1,600 were made on foot with carriers. A line of stations was secured along almost the entire length of the eastern coast, another roughly parallel along the high plateau east of the central axis of the island, and a line of stations more widely spaced along the western coast, thus completing a very satisfactory distribution of stations.

Mr. Brown returned to Africa after the completion of the Madagascar program to make observations at selected repeat stations, particularly those of 1909 by Professors Beattie and Morrison. He arrived at Zanzibar July 8, and at Dar-es-Salaam, July 11. After a railway journey inland to Ujiji, Lake Tanganyika, he next went to Mombasa, Kenya Colony, and inland by railway to Kisumu (Port Florence) on Lake Victoria. During these two trips he reoccupied 11 stations of 1920 besides other selected stations along the railway lines. Leaving Mombasa on August 24, he arrived at Aden, Arabia, on August 29, and sailed for Jibuti, French Somaliland, which was reached on September 3. From this point he traveled inland to Addis Abeba, Abyssinia, where he reoccupied Mr. Wallis's station of 1914, and Mr. Sawyer's station of 1918, and on his return two intermediate repeat stations along the railway. The data for secular-varition thus secured along the east coastof Africa are especially valuable and well distributed.

In order to close satisfactorily the work and to control the instrumental constants as required after so severe and long a campaign, Mr. Brown proceeded by way of Aden, Arabia, and Colombo, Ceylon, to the Watheroo Magnetic Observatory, in Western Australia, and secured a comparison of standards while still in the southern magnetic hemisphere. After having obtained these comparisons, Mr. Brown completed his field work, which has extended over a continuous period of 2½ years and will return to Washington by way of Singapore and Canton.

ASIA.

The work of the "*Maud* Expedition," under the command of Captain Roald Amundsen, with whom the Department is cooperating, was continued into 1921, but it was suspended temporarily later in the year because of return of the expedition to Seattle for repairs of vessel.

During the winter of 1920–1921, observations were made at the winter quarters of the *Maud* at north latitude 66° 53′ and west longitude 171° 39′ on Chukchen Peninsula in eastern Siberia. A sledge journey was undertaken in February to April around the coast south and west as far as Holy Cross Bay, and inclination and intensity observations with a Dover dip circle were made at 11 stations; approximate declinations were also secured when conditions were favorable. An attempt on the return to cross the peninsula from the Gulf of Anadyr on the south to Kolyuchin Bay on the north was unsuccessful on account of the deep snow. In April, observations were made at Pitlekai, where Nordenskjöld wintered in 1878–1879. The suspension of the work of the expedition in order to permit necessary alterations and repairs to be made to the vessel allowed an opportunity for Dr. H. U. Sverdrup, who with Mr. O. Wisting had made a great part of the magnetic observations, to come to Washington. He arrived on October 25 with the magnetic instruments, which he will compare with the standards of the Department.

On his journey from the eastern coast of Africa to Watheroo, Western Australia, Observer F. Brown visited the Department's secular-variation station at Aden, Arabia, making observations there early in September, and later in the month at the Admiralty station of 1909 situated across the harbor. Leaving Aden on September 26, he proceeded to Colombo, Ceylon, where the station at that point was again reoccupied.

AUSTRALIA.

Absolute observations, as well as continuous photographic registrations, have been made throughout the year at the Watheroo Magnetic Observatory (see page 328). On October 23 Observer Brown arrived at Watheroo after the completion of his work in Africa and compared his instruments with the observatory standards. At the end of the month he was engaged with Assistant Observer J. Shearer in reoccupying a few of the Department's stations in Western Australia. Observer D. G. Coleman arrived at Sydney from Fiji Islands on October 14, and reoccupied the stations at Red Hill and East Maitland.

ISLANDS, PACIFIC OCEAN.

Mr. Coleman, as a member of Dr. H. M. W. Edmonds's party, after the completion of the *Carnegie's* observations at Apia, Samoan Islands, in July 1921, began the reoccupation of a series of stations occupied in 1906 and 1915 among the islands of the South Pacific Ocean, and by the middle of October had occupied 9 stations in the Ellice, 3 in the Tokelau, 2 in the Tonga, and 2 in the Fiji islands. From Fiji he went to Sydney, Australia, to arrange for further work among the Solomon Islands.

The *Carnegie* made observations at Christchurch, New Zealand, in the latter part of October and early November at two of the stations previously occupied, comparing standards of the Department with those of the Christchurch Observatory. The station at Point Fareute, Tahiti, was reoccupied in December 1920. Valuable series of observatory intercomparisons were obtained in April 1921 at the Honolulu Magnetic Observatory, and in June and July 1921 at the Samoa Observatory. Lack of satisfactory anchorage at Fanning Island unfortunately made it inadvisable to delay vessel for observations there.

SOUTH AMERICA.

Absolute magnetic observations were made at the Huancayo Observatory by Magnetician W. F. Wallis, assisted until September by Observer W. H. Wood. The complete program of magnetic-variation observations at the Observatory was to be begun in January 1922.

NORTH AMERICA.

In cooperation with the MacMillan Arctic Association, the Department provided the MacMillan Baffin Land Expedition with equipment for making magnetic, atmospheric-electric, and polar-light observations. Mr. G. Dawson Howell jr., a member of the expedition, was given at Washington the necessary training for field and observatory work. He, with the aid of Mr. Richard H. Goddard, of the Department staff, will set up a complete magnetograph outfit in a temporary observatory to be erected near the expedition's winter-quarters; it is hoped that the observatory work may be continued for at least 8 to 10 months. During the winter (1921–22) it is planned to make magnetic exploration trips starting out from the winter-quarters, which will probably be in the vicinity of Fury and Hecla Strait. The expedition's vessel, the *Bowdoin,* sailed from Wiscasset, Maine, on July 16, and from East Booth Bay, Maine, on July 18. Observations were made at Sydney, Nova Scotia, and at Battle Harbor, Labrador, from which point the expedition proceeded north early in August. Important secular-variation data will be obtained at stations en route to the winter-quarters.

During the *Carnegie's* stay at San Francisco, California, in February and March 1921, observations were made at Fort Scott and at the repeat station, San Rafael. At Fort Scott also comparisons were made of the ship standard instruments with the Department's sub-standard magnetometer-inductor No. 26 which Mr. Fleming had brought to San Francisco on his inspection trip to the vessel. On Mr. Fleming's return to Washington, magnetometer-inductor No. 26 was compared with the Department's standards, thus insuring effective control of the corrections for the *Carnegie* instruments and for the valuable series of observatory intercomparisons obtained during the vessel's calls at Christchurch, Honolulu, and Apia.

OBSERVATORY WORK.

WATHEROO MAGNETIC OBSERVATORY.

Magnetician E. Kidson, having accepted the appointment of supervising meteorologist in the Central Weather Bureau, at Melbourne, resigned from the Department on January 31, 1921, and his duties as observer-in-charge at Watheroo were taken over by Observer W. C. Parkinson, previously chief assistant. On December 7, 1920, Mr. J. Shearer reported for duty at the Observatory as assistant observer. The following summary of the work during the year is taken from Mr. Parkinson's report:

The magnetographs have been in continuous operation throughout the year. Daily meteorological observations, weekly determinations of absolute magnetic elements, weekly time observations until the installation of the wireless apparatus, and monthly scale-value determinations for the variometers were made. All preliminary reductions of the traces, computations of observations, with necessary checkings, together with the necessary routine work, have been carried out and the records and tabulations despatched to Washington month by month. A notable magnetic disturbance was recorded on May 13 to 17, 1921, and was accompanied by an auroral display observed at Watheroo on the evening of May 16.

Meteorological data have been regularly supplied, as in previous years, to the Commonwealth Weather Bureau, and information regarding abnormal magnetic conditions has been furnished from time to time to the telegraphs branch of the Commonwealth Postal Department.

Special determinations of the latitude of the Observatory have been made and reduced. *The adopted latitude is 30° 19′ 05.″3 south; the longitude, previously adopted, is 115° 52′ 38″ east of Greenwich.*

During the year, in addition to the various routine, repair, and maintenance work on buildings and site, the following improvements have been effected:

(1) The additions to the observers' quarters, begun in October 1920, have been completed, the attic space has been floored, and the roof covered with asbestos tiles.

(2) All the buildings have been repainted.

(3) An underground cistern, of about 2,000 gallons capacity, has been constructed at the auxiliary quarters to provide additional storage of rain-water for use during the dry summer months.

(4) A well, 20 feet deep, has been sunk near the observers' quarters and an elevated tank and a windmill erected above it. (The water from this well was afterwards condemned by the Government Bacteriologist for drinking purposes, but the water will be of great service for use in the garden and orchard during the summer, while the elevated tank and windmill are now used to send a supply of rain-water from the underground cistern running through the quarters.)

(5) A wireless receiving outfit has been put into operation, and time signals from Perth Observatory are recorded regularly.

(6) The roofs of the variation and absolute observatories and the auxiliary quarters have been painted with Malthoid Red Coating, which, while preserving the felt roofing, has greatly improved the quality of the rain-water obtained thereform.

(7) An area of 37 acres around the buildings has been completely cleared of native scrub and planted with wheat, oats, and barley.

(8) A 1,250-watt electric-generator and storage-battery equipment for use in connection with proposed atmospheric-electric work was installed in the auxiliary quarters, one room of that building having been suitably altered and arranged for mounting of the plant. Electric wiring for lighting of buildings was completed and electric fixtures installed in observers' quarters and office; all electric leads in the office and variation observatory were twisted to eliminate any disturbance that might otherwise be caused by them.

(9) The central atmospheric-electric and earth-current instrument-house was begun in accordance with the plans prepared at Washington.

Dr. G. R. Wait, assistant physicist, left San Francisco on September 6 for Watheroo, where he arrived about October 15. He took with him a large part of the standard atmospheric-electric equipment for installation at the Observatory and the carefully standardized magnetometer-inductor No. 27. Meanwhile, Mr. Parkinson proceeded with the construction of the special double-wall, concrete atmospheric-electric house for installation of the apparatus. As soon as Dr. Wait has become thoroughly familiar with the observatory work he will relieve Mr. Parkinson, who will return to Washington via Africa, Spain, France, Holland, and England, securing en route secular-variation observations at a few stations in Africa and comparisons of observatory standards at the chief observatories in Europe, using magnetometer-inductor No. 27. Respecting Mr. Parkinson's services, see page 313.

The crown grants and deeds for the site, some 200 acres, and vesting orders for the two 10-mile earth-current strips, generously donated for the use of the Observatory by the government of Western Australia, were completed and filed during the year. It is a pleasure to record the continued interest shown in the Observatory by the government officials and men of science.

HUANACAYO MAGNETIC OBSERVATORY.

The construction of buildings was continued under the charge of Dr. H. M. W. Edmonds, magnetician, until March 31, when he left for San Francisco, California, for a brief vacation before assignment to the Pacific work. His successor at Huancayo, Mr. W. F. Wallis, joined him in Peru on January 24, 1921, and continued in charge from April 1 throughout the year. Mr. W. H. Wood, observer, assisted Mr. Wallis from May 28 to September 5, 1921. Mr. Wood brought to the Observatory the carefully standardized magnetometer-inductor No. 28 for use in comparisons at Huancayo and for possible field work later. Mr. A. Smith, foreman carpenter, returned to duty at Washington February 10.

Thanks to the energy shown by Mr. Wallis, the progress of the construction work, which had been well advanced by Dr. Edmonds during his assignment to Huancayo of over two years, was very satisfactory, despite delayed deliveries of materials and supplies. The party took up residence at the Observatory site on May 3, using the absolute observatory as quarters pending the completion of the bungalow intended for observers' quarters. The trimming out and finishing of buildings were done by Peruvian carpenters, Mr. Wallis having obtained the services of first-class mechanics from Lima and from Chupaca. Efforts were concentrated upon the completion of the variation observatory, and the magnetograph was installed and in operation by October. Absolute magnetic observations were made weekly beginning in June, and monthly scale-value determinations for the variometers were begun in October. Daily meteorological observations were obtained throughout the year. Time observations were made at irregular intervals until the beginning of the magnetograph work, since which time they were made weekly.

The first attempt to get water by a well had to be given up after digging to a depth of 46 meters. A second well was started in August at what seems to be a more favorable location on the site, and it is hoped that water may be found within a depth of 45 meters. Meanwhile, water for living purposes and for construction work during the dry season must be carried by burros from the Chupaca River, about a mile distant.

A small electric generator and storage-battery equipment were purchased for use in connection with atmospheric-electric registrations, to be undertaken later, and for lighting buildings and instrument registers. This plant is to be installed in a room of the small 4-room concrete building, which was built near the quarters for laundry, servants' quarters, and storage. Materials were purchased and construction begun on the central atmospheric-electric and earth-current instrument-house, which is similar to that being built at Watheroo. A corral was built for the horses, the corners of the site were marked by concrete monuments, paths between buildings were completed, and fencing and improvement of site were begun.

As in past years, the Peruvian Government extended every facility to Dr. Edmonds and to Mr. Wallis and granted the privilege of free entry for all materials and apparatus. Numerous courtesies and valuable assistance were also received from the American Ambassador at Lima.

MISCELLANEOUS OBSERVATORY WORK.

Atmospheric-electric observations at Washington, District of Columbia.—See page 333.

Atmospheric-electric observations at Apia, Samoa.—See statements on pages 312 and 333.

Comparisons of magnetic observatory standards.—An extensive series of such comparisons with the Department's standards was obtained at various places and will be found mentioned in the respective field reports. Furthermore, Dr. Otto Klotz, director of the Dominion Observatory of Canada, kindly communicated the results of comparisons made at different times during 1915 to 1920 between the Dominion Observatory magnetometer No. 20 of the C. I. W. universal type[1] and the standards of the Agincourt Magnetic Observatory. At Dr. Klotz's request, comparisons were made during May and June 1921 at Washington between Dominion Observatory magnetometer No. 20 and the Department standard magnometer No. 3. Accordingly, indirect comparisons between the adopted Agincourt standards and those of the Department were also obtained.

Observatory Work of MacMillan Baffin Land Expedition.—The plans were completed for proposed temporary observatory work at the winter-quarters of the MacMillan Baffin Land Expedition (see pp. 327 and 334). A small non-magnetic building for the installation of magnetograph and of potential-gradient apparatus was designed and the necessary materials and instrumental accessories were purchased and constructed. The magnetograph to be used is of the Eschenhagen type and includes variometers for declination, horizontal intensity, and vertical intensity; the latter variometer was courteously loaned by the U. S. Coast and Geodetic Survey. The potential-gradient apparatus was designed and constructed in the Department.

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[1] See "Researches of the Department of Terrestrial Magnetism," Vol. II, 7–9, 1915.

DETAILS OF INVESTIGATIONAL AND EXPERIMENTAL WORK.

DIVISION OF RESEARCH IN TERRESTRIAL MAGNETISM AND ELECTRICITY.

This division has continued under the immediate charge of the Director and its work consists of investigations bearing upon the phenomena and causes of the Earth's magnetic field and of its electric field and of their variations (secular, annual, diurnal, and spasmodic).

Magnetic observations during solar eclipse of May 29, 1919.—Some further progress was made with the analysis of the magnetic effects observed during the solar eclipse of May 29, 1919. The analysis could not be wholly completed, pending the receipt of additional data from cooperating observatories. A first summary of results was published in full in the September 1920 issue of *Terrestrial Magnetism and Atmospheric Electricity*, and an abstract was given in the annual report of last year. It is hoped that a second summary may soon be published.

Volume IV of Researches of Department of Terrestrial Magnetism.—Various assistance was rendered by members of the division in the preparation of the manuscripts of this volume.

Vertical electric currents and the relations between terrestrial magnetism and electricity.—A brief statement of the bearing of this problem upon the theory and composition of the Earth's magnetic and electric fields will be found on page 314. Preliminary results of the computations were published in *Terrestrial Magnetism and Atmospheric Electricity* for December 1920 (see abstract on pages 347–348).

Magnetic and allied effects, May 13–16, 1921.—The striking geophysical effects which accompanied the remarkable sun-spot activity during the middle of May 1921 were briefly described on pages 307 and 309. In view of the general interest shown, data are being collected from various sources and an analysis is to be undertaken.

Measures of the electric and magnetic activity of the Sun and the Earth, and interrelations.—Various results of this comprehensive investigation have been presented before the April meeting of the section of Terrestrial Magnetism and Electricity of the American Geophysical Union, the general meeting of the American Philosophical Society at Philadelphia in April, and before the Philosophical Society of Washington in May. The paper as published in the March-June issue of *Terrestrial Magnetism and Atmospheric Electricity* comprises the following topics: I: General considerations and remarks; II: Measure of the Sun's activity; III: Measure of the Earth's magnetic activity; IV: Relations between solar activity and the Earth's magnetic and electric activity (see abstract on pages 348–351). A second paper is in preparation.

New measures of solar activity and the "Earth-effect."—Brief reference was made to this investigation on page 309. A paper was presented before the Astronomical Society in August (see abstract on pages 350–351).

The following persons have taken chief part in the work described: L. A. Bauer, W. J. Peters, J. A. Fleming, H. W. Fisk, S. J. Mauchly, C. R. Duvall, C. C. Ennis. Assistance was also received throughout the year from Mr. H. D. Harradon and Miss Emma L. Tibbetts, and likewise during the summer of 1921 from Dr. James E. Ives, while temporarily associated with the Department, and from Mr. G. H. Keulegan, assistant physicist, November to December, 1920.

SECTION OF TERRESTRIAL ELECTRICITY.[1]

The principal activities during the year under review have been as follows:

1. *Reduction of atmospheric-electric observations.*—The reduction of ocean atmospheric-electric observations, referred to in the report of last year, has been continued, with preliminary reports from time to time on various phases of the diurnal variation of atmospheric-electric elements as derived from observations made aboard the *Carnegie*. (See abstract, pp. 354–356.) The full publication of data and discussion of results will be deferred until after the completion of the *Carnegie's* present cruise. Considerable headway has also been made in the reduction of the continuous records of potential gradient and conductivity obtained in the atmospheric-electric observatory at Washington.

2. *Ocean atmospheric-electric observations.*—The current reports from the *Carnegie* regarding ocean atmospheric-electric work have been studied in detail and various modifications and additions to the original instructions for the present cruise have been prepared.

3. *Observatory work at Washington.*—The observatory maintained on the deck of the Laboratory at Washington, primarily for experimental purposes in connection with the development of equipment for the geophysical observatories of the Department, has been continued throughout the year, except for short periods when prevented by special tests in the course of development work and by the training of observers. In addition to the regular work of operating the observatory, standardizing observations were carried out which have made it possible to proceed with an approximate reduction (mentioned above) of the records thus far obtained.

4. *Observatory work at Apia, Samoa.*—While Dr. H. M. W. Edmonds was stationed at Apia in charge of the secular-variation work in terrestrial magnetism pertaining to the islands of the Pacific Ocean, he also made observations of the potential-gradient and allied meteorological observations at the Apia Observatory in accordance with cooperative arrangements between the Department and the New Zealand government (see p. 312).

5. *Design of equipment for atmospheric-electric observatories.*—In conjunction with the chief of the magnetic-survey division, designs

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[1] Report of the chief of the section, S. J. Mauchly.

were prepared and detailed attention given to the preparation of the drawings for apparatus of observatory type for securing continuous photographic records of positive conductivity (λ_+), negative conductivity (λ_-), and potential gradient. The conductivity apparatus is a duplex system, consisting of one unit for (λ_+) and one for λ_-. Each of these units is a modification of the ordinary Gerdien conductivity apparatus similar in general to that described by Swann,[1] but including various modifications and improvements which have resulted from several years' experience with the above-mentioned apparatus in the deck observatory at Washington.

For recording the potential gradient, an ionium collector and quadrant electrometer are employed in the customary manner. All complex mechanism has been avoided in both of the above designs and especial care has been taken to secure accessibility and easy removal of all parts requiring occasional inspection and cleaning. Furthermore, all parts are of standardized dimensions, in order to facilitate any repairs or replacements which may become necessary.

6. *Work in connection with the MacMillan Baffin Land Expedition.*—After a study of the conditions likely to be encountered, it seemed feasible to attempt to secure continuous potential-gradient records at the expedition's winter-quarters during the winter of 1921–22. Because of the climatic conditions peculiar to the polar regions, it was necessary to provide, in the instrument shop of the Department, practically all of the required equipment, either by the modification of existing apparatus or by new construction. The special designs prepared for this work provide for the continuous photographic registration of the potential gradient in a manner similar to that described above. Mr. G. Dawson Howell jr., of the Expedition, who will have direct charge of the atmospheric-electric work, was given training and instruction therein.

In addition to the potential-gradient observations, provision has been made to secure various meteorological data. While these are desired primarily for use in connection with the reduction and interpretation of the potential-gradient observations, they will doubtless also be of considerable value to general meteorology; the meteorological equipment and forms were supplied by the United States Weather Bureau.

Considerable attention was also given to the program of work and preparation of equipment for the auroral observations to be carried out by the Expedition. Especial attention was given to the photographic equipment and to the problem of securing suitable means of communication between the two stations at which it is desired to secure simultaneous photographs of the aurora. The field telephone equipment carried by the expedition was supplied by the United States Signal Corps.

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[1] See Annual Report of the Director of the Department of Terrestrial Magnetism, Year Book of the Carnegie Institution of Washington for 1917, p. 279.

One of the vital problems in connection with atmospheric-electric and telephonic work in polar regions is the securing of suitable batteries for operation at low temperatures. Much valuable assistance was rendered in this connection by the Bureau of Standards, which supplied a large amount of the data upon which final selection was based.[1]

7. *Miscellaneous.*—The Department has continued to cooperate with the Radio Laboratory of the Bureau of Standards in its study of the "swinging" of radio signals on short wave-lengths, especially by making it possible for the Bureau to secure copies of all available atmospheric-electric records suitable for the work in hand.

The chief of the section, in accordance with instructions from the Director, assumed charge of the instrument shop for portions of February, March, and July, during temporary absences of Mr. Fleming on official business.

For publication work see abstract, pages 354-356.

Valuable assistance has been rendered in the work of the section by Dr. G. R. Wait, assistant physicist, and Mr. C. M. Little, assistant observer. Dr. Wait was transferred to the Magnetic Survey Division on July 18, preparatory to his departure to assume charge of the Department's observatory at Watheroo, Western Australia, where he will make the initial installation of the observatory atmospheric-electric equipment referred to on page 333. During the months of February, March, and April, approximately half of Dr. Wait's time was devoted to work on the sine galvanometer under Dr. Barnett.

ADMINISTRATIVE DIVISION.[2]

Line integrals of the magnetic force.—Line integrals of the Earth's magnetic force along various parallels of latitude on the surface of the Earth were computed in connection with the Director's investigations concerning vertical currents (see pp. 347 and 348). Material assistance in this work was given by Mr. G. H. Keulegan, temporarily engaged as assistant physicist to December 31, 1920. The line integral of the magnetic force along the sub-antarctic track of the *Carnegie,* December 6, 1915, to April 1, 1916, was also computed, with the assistance of Mr. C. R. Duvall, based entirely upon the *Carnegie* results. The computation along the ship's track was somewhat complicated by the number of magnetic stations made during a day, which necessitated deducing the course and distance between stations selected, one for each day (preferably the daily dip and intensity station), and then reducing the various declination results of the day to these stations;

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[1] The investigations made by the Bureau are described in a paper on "The Electromotive Force of Cells at Low Temperatures," by G. W. Vinal and F. W. Altrup. J. Wash. Acad. Sci., v. 12, 1922.

[2] From the report of W. J. Peters, in charge of the division.

the average parallel was about 52° S. Declinations had been observed aboard the *Carnegie* generally twice a day throughout the passage of 118 days, and horizontal intensities and inclinations were observed once a day. The preliminary computations gave a total resultant negative current passing from the air perpendicularly through the surface of the zone, from the South Pole to the circuit, of 80 times 10^4 amperes, which corresponds to an average current-density of 0.016 ampere per square kilometer.

Average diurnal changes.—Preliminary values of the average annual changes in the magnetic elements over the Indian Ocean were deduced from the *Carnegie* results obtained in 1911, 1916, and 1920. The work was begun by the commander of the *Carnegie*, J. P. Ault, while at sea on Cruise VI, and has been amplified subsequently in the office. Two methods were used, based upon the assumption that differential corrections to the results for small differences in the geographic coordinates may be computed with sufficient accuracy from data derived from the most recent magnetic charts. These two methods are somewhat shorter than those described in Volume III (pp. 431–432) of the "Researches of the Department of Terrestrial Magnetism," but the latter methods have the advantage of being entirely independent of the approximative data required and obtainable at present only from the charts.

Standardizing instruments.—The resumption of field activity, not only by the Department, but also by other organizations interested in magnetic work, both American and foreign, placed unusual demands upon the Department's facilities for the standardizing of field instruments. The chief of the division accordingly assisted the Magnetic Survey Division in this work by making comparison observations simultaneously with Mr. H. W. Fisk between May 25 and July 8, 1921.

Field reports.—Considerable time was given to editing the reports by field parties. These reports by different observers, written in remote parts of the world under most varied and trying conditions, contain a large amount of valuable and interesting material, all of which, however, is too voluminous to publish. With the help and advice of the Magnetic Survey Division, the material was carefully condensed and prepared for publication in Volume IV of the "Researches of the Department of Terrestrial Magnetism."

The table of magnetic results for Volume IV was completed by Miss Tibbetts under the supervision of the Magnetic Survey Division. Blue prints and manuscript forms for various investigations and reports have been made from time to time by Mr. Dixon. Memoranda for the determination of the height of the aurora were prepared for the use of the MacMillan Baffin Land Expedition. The first audit of the monthly disbursements made by the various divisions, expeditions, and observatories, involving in many cases problems of fluctuating foreign exchange, have been carefully made by M. B. Smith, who also prepared all financial statements.

The personnel of the division during the year included W. J. Peters, chief; C. R. Duvall, expert computer, to January 1, 1921, when he was transferred to the Division of Research in Terrestrial Magnetism and Electricity; M. B. Smith, chief clerk and cashier; Miss Emma L. Tibbetts, stenographer and computer; A. J. S. Dixon, messenger clerk.

MAGNETIC SURVEY DIVISION.[1]

Mr. J. A. Fleming continued as chief of the Division throughout the year, with the effective cooperation of Mr. H. W. Fisk as chief of the Section of Land Work. Captain J. P. Ault was chief of the Section of Ocean Work and was in command aboard the *Carnegie* throughout the year (for report see pp. 317-323). Mr. Fleming was on an inspection trip to the *Carnegie* during February 20 to March 13 while she was at San Francisco, and again during July 13 to 18 to the *Bowdoin* of the MacMillan Baffin Land Expedition at Wiscasset, Maine. In his absence, Mr. Fisk was acting chief of the Division.

Reduction of magnetic results.—The comparisons and revisions of observations and compilation of resulting data obtained during 1920 at land stations were completed and included in the manuscript for Volume IV of the Department's "Researches." The reductions of the field observations made during 1921 were kept current. Good progress was also made in the reductions of the observations obtained during November 1918 to July 1920 by the "*Maud* Expedition," under the leadership of Captain Roald Amundsen (see p. 325); Mr. Duvall did most of this work.

Instrumental constants and standardizations.—An extension of the discussion of constants for standard magnetometer No. 3, to include the years 1920 and 1921 (to September), was made; the series of observations with this instrument now covers a period of 15 years from 1907. The results of the discussion indicate that only a small correction will be necessary to values of horizontal intensity based on the constants originally adopted. To reduce the labor of computation for distribution cooefficients of magnetometer constants, Mr. Fisk developed a simplified form of the well-known formulæ already in use. Further extension was also made of the investigation undertaken by Mr. Fisk on dip-needle errors arising from minute pivot-defects. Extensive comparisons with the Department's standard magnetometer No. 3 and earth-inductor No. 48 were made for instruments used or to be used in the field to determine their corrections. All comparisons were made by the method of simultaneous observation with exchange of station. Some trouble was experienced because of increasing disturbance caused by leakage from electric-car circuits about five-eighths mile to the west. Strict simultaneity of comparison observations eliminated any harmful effects from this source. Observations were made to determine the moments of inertia for the long-magnet systems of magnetometers Nos. 3, 16, 20 (2 series), 24, 26, 27, and 28. While no change was found in the case of No. 3, the gradual change with time for magnets of the type used for the other instruments reported in last year's report[1] was confirmed. The results of the comparisons of instruments were very satisfactory; Mr. Fisk made all the observations with the standard instruments, while Mr. Peters did a large part of the work required for the other instruments; Messrs. Duvall and Ennis have assisted in the reductions.

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[1] From the report of J. A. Fleming, in charge.

Correlation of magnetic standards.—This investigation was continued, utilizing the additional observatory comparisons obtained by field parties during the interval 1914 to 1921. The general conclusions resulting from the discussion of earlier comparisons (see pp. 211 to 278, Vol. II of the Department's "Researches") are further confirmed.

Absolute standard in horizontal intensity.—Upon the completion of sine galvanometer No. 1, constructed according to the design by Dr. Barnett, an investigation as to an absolute standard in horizontal intensity was begun by Messrs. Fleming, Fisk, and Ives. Extended comparisons were made between the sine galvanometer and Department standard magnetometer No. 3, and a preliminary report was prepared on the results. The agreement between the instruments is satisfactory and indicates that an absolute accuracy of $0.0002H$, where H is the horizontal intensity, can be readily secured with well-designed magnetometers. The sine galvanometer functioned well, the limitations as to precision of results depending upon the accuracy with which the electrical current could be measured with the accessory apparatus; there appears little reason to doubt that, even with the somewhat experimental apparatus for current measurements used in this preliminary work, a precision of $0.0001H$ is readily obtainable. It is planned to extend the work later by using different methods for measurement of current and to make improvements in switch-and-circuit arrangements, as well as to provide small, portable-type storage-batteries for current.

Instructions and development of field work.—The resumption of greater activity in field work since April and necessary preparation of instructions and training of new observers consumed much time.

Miscellaneous work.—Assistance in making drawings for various purposes was given by Mr. Ennis. The greater part of the miscellaneous, clerical, and stenographic work in the Division was efficiently done by Mr. J. J. Capello, property and shipping clerk.

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[1] *Cf.* Annual Report of the Director of the Department of Terrestrial Magnetism for the year 1920, Year Book of the Carnegie Institution of Washington, p. 302.

INSTRUMENT WORK.

The classification of work done in the instrument shop during the year was about as follows: equipment, 54 per cent; experimental, 28 per cent; improvements and repairs of instruments and buildings, 10 per cent; miscellaneous and stock, 8 per cent.

The principal new work was the preparation of designs and drawings for standardized atmospheric-electric conductivity apparatus (both positive and negative) and potential-gradient apparatus, with photographic registration, together with panel boards and special appurtenances for observatory use. About 20 detail and assembly tracings showing this equipment were made by Mr. Huff and work on 3 duplex conductivity and 3 potential-gradient apparatuses was started. The conductivity apparatus for use at the Watheroo Magnetic Observatory was completed and assembled for test in the laboratory; it was packed and forwarded to Watheroo in August 1921.

Other new work included construction of 4 ionization chambers for observatory use, completion of sine galvanometer No. 1 (instrumental work completed March 25), and preparation of special equipment, including potential-gradient apparatus for continuous photographic registration, for use in cooperation with the MacMillan Baffin Land Expedition. This special equipment included also 3-ply and 5-ply wooden piers and pier-tops for temporary observatory building, and electric-lamp housings for magnetograph and potential-gradient photographic registers. A compass attachment for dip-circle was also designed and constructed for use during sledge trips by the expedition; the sights are so arranged that azimuths of celestial bodies at altitudes not exceeding 20° may be observed. Thus the dip circle, in connection with a sextant and artificial horizon for time work, becomes a universal instrument for complete determination of the magnetic elements, declination, inclination, and total intensity.

Non-magnetic castings required for instruments were made, as heretofore, in our own foundry under the direction of Mr. C. Huff. About 1,000 pounds of non-magnetic brass, bronze, bell-metal, and "lumen" were cast during the year. The excellent character of the metals cast in our foundry is evidenced by the severe tests made of the metal parts used in the construction of the sine galvanometer; thus the copper damping-box casting for this instrument was shown by Dr. Barnett's delicate tests to be slightly diamagnetic. The brass castings for the new standard atmospheric-electric equipment in construction, which totaled about 950 pounds and which were not required to be non-magnetic, were cast by a local brass-founder.

The shop personnel consisted of Messrs. C. Huff, G. H. Jung, W. F. Steiner, instrument-makers; A. Smith, carpenter and pattern-maker (from February 10 after his return from observatory field-duty); and

J. G. Lorz, mechanician. Mr. Huff has been engaged chiefly on design and construction of the standard observatory atmospheric-electric apparatus, under Dr. Mauchly's immediate direction, and in making drawings for atmospheric-electric instrument-house at our observatories; he was also engaged in special foundry work and in preparing special equipment for the MacMillan Baffin Land Expedition. Mr. Jung has worked chiefly on completion of the sine galvanometer, under Dr. Barnett's direction, and upon construction of standard atmospheric-electric apparatus. Mr. Steiner has been responsible for the greater part of the new and repair work on magnetic instruments and the preparation of field equipments. Mr. Smith has worked chiefly on special mill-work for the Huancayo Observatory, on cabinet and pattern work, and on packing of equipment for shipment. Mr. Lorz, in addition to looking after numerous miscellaneous duties, has worked chiefly on repair work and construction of atmospheric-electric apparatus parts.

BUILDING AND SITE WORK IN WASHINGTON.

Numerous details in connection with the purchase, concluded in April 1921, of additional ground to the north of the original site were looked after. The net addition totalled 75,077 square feet. The site now totals 8.76 acres, and is bounded on all sides by existing streets and roads or by lines of proposed streets according to the permanent plan of highways by the District of Columbia. A topographic survey of the extension was made, and various improvements on the site were made.

Terra-cotta drains were provided to care for rain-water from roof of the Standardizing Magnetic Observatory. An extension, 10 feet by 20 feet, was made at the north end of the stable for housing of tools. Three 20-inch, all-copper ventilators were installed on the roof of the Experiment Building, and suitable non-magnetic ducts leading to them were built. Several non-magnetic piers were built in the Experiment Building, as also non-magnetic mounts for galvanometers and accessory apparatus were provided in the Standardizing Observatory.

In conclusion, especial mention must be made of the zealous interest and initiative shown by every member of the Department's personnel who has had any part in the work of the Magnetic Survey Division.

DIVISION OF EXPERIMENTAL WORK.[1]

Throughout the year Dr. Barnett has continued to work chiefly on the investigations which were in progress in 1920, those on magnetization and rotation and the sine galvanometer.

Sine galvanometer No. 1 has been completed and installed in the Standardizing Observatory, and all the tests have indicated that it is entirely satisfactory. The manuscript on the instrument is now in course of publication. A paper on the instrument was presented to the American Geophysical Union on April 18, 1921 (see abstract, pp. 346–347).

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[1] From the report of the chief of the division, S. J. Barnett.

Magnetization and rotation.—No further work on rotation by magnetization has yet been practicable and in the work on magnetization by rotation only a slight amount of progress has been made in further preparation for the experiments on large rods by the method of electromagnetic induction. A great deal of work, however, has been done by the magnetometer method; and much progress has been made in the elimination of systematic errors. The possible error due to non-uniformity of speeds has been removed or reduced by the substitution of gear drive for belt drive. The effects of torsion have been studied more thoroughly and have been more completely eliminated. Eddy-current effects have been further studied by superposing on the residual field in which the rotor moves cross-fields and longitudinal fields; and they have been further eliminated by reversing the magnetometer system and by transferring the rotating apparatus to a new compensating frame which produces a much more nearly uniform magnetic field than that of the frame used before. Experiments have been made with four positions of the magnetometer. Other improvements are in progress. An account of this work up to December 1920 was presented by S. J. and L. J. H. Barnett at the Chicago meeting of the American Physical Society. (See *Physical Review*, 17, 1921, p. 404.)

In connection with the magnetic tests on the materials of the sine galvanometer, a little attention has been devoted to the general problem of measuring small susceptibilities with astatic magnetometers.

At the joint meeting of the American Physical Society, and the American Association for the Advancement of Science, Section B, in December, Dr. Barnett presented, by invitation, an extended paper on "The Electron Theory of Magnetism," an abstract of which will be found on pages 345–346. The complete paper is published in *Science*, n. s. vol. 53, 1921, p. 465.

In *Nature*, March 3, 1921, he published a brief paper on "Molecular and Cosmical Magnetism," an abstract of which is given on page 345.

He has continued to serve on the National Research Council committees on "Electrodynamics of Moving Bodies" and "Theories of Magnetism."

Mr. Kotterman has continued his valuable services in instrumental work, laboratory assistance, photographic work, and clerical work.

From this division, Mr. Huff, after finishing two excellent gear boxes for use in the fundamental work in magnetism, was transferred to work on the sine galvanometer, and later to work under Dr. Mauchly's supervision; Dr. Wait and Dr. Ives have rendered important services in connection with the linear measurements upon the coils of the sine galvanometer; and Mr. Jung has done the chief instrumental work on this instrument.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS.

Preliminary results of ocean magnetic observations on the *Carnegie* from Colombo, Ceylon, to Fremantle, Western Australia, and Lyttelton, New Zealand, July to October 1920. J. P. Ault. Terr. Mag., vol. 25, 145–162 (December 1920).

Preliminary results of ocean magnetic observations on the *Carnegie* from Lyttelton to Tahiti, Fanning Island, San Francisco, and Honolulu, November 1920 to April 1921. J. P. Ault. Terr. Mag., vol. 26, 15–24 (March–June 1921).

Preliminary results of ocean magnetic observations on the *Carnegie* from Honolulu to Pago Pago, April to June, 1921. J. P. Ault. Terr. Mag., vol. 26, 91–95 (September 1921).

These three papers give the preliminary results of the magnetic observations on the *Carnegie* during the present cruise (No. VI) during July 1920 to June 1921. Notes on the various passages are given; in addition to the general details of the passages, they include pertinent remarks regarding auxiliary observations, determinations of currents, and corrections determined for geographical positions of islands in the Pacific which were visited.

Table 1 will serve to show for the period, October 1920 to October 1921, the magnitudes of the chart differences as determined from a comparison of the *Carnegie* observed values of the magnetic elements with values scaled from the most recent magnetic charts: For *declination*, U. S. Hydrographic Office No. 2406 for 1920 and British Admiralty Nos. 3776 and 3777 for 1917; for *inclination*, U. S. Hydrographic Office No. 1700 for 1920; and for *horizontal intensity*, U. S. Hydrographic Office No. 1701 for 1920. The new material for these charts was supplied almost entirely by the Department of Terrestrial Magnetism. Secular variation corrections were applied to the magnetic declinations scaled from the charts.

In order to explain the significance of the letters *E*, *W*, *N*, *S* as affecting the application of the chart differences, it may be stated that *E* and *N* have been treated as being plus, *W* and *S* as minus, the chart difference being equal to the *Carnegie* value minus the chart value. The horizontal intensity is always regarded as positive, and the signs, plus and minus, have their usual significance.

TABLE 1.—*Range in chart differences, October 1920 to November 1921.*

Cruise VI.	Date.	Declination.		Inclination.	Horizontal intensity.[1]
	1920–1921.	British.	U. S.	U. S.	U. S.
Fremantle-Lyttelton...	Oct. 1–Oct. 20	0°5 W to 1°5 E	0°7 W to 1°6 E	0°4 N to 0°8 S	+4 to −5
Lyttelton-Tahiti.......	Nov. 19–Dec. 22	0.5 W to 1.2 E	0.7 W to 1.2 E	1.0 N to 1.1 S	+8 to −9
Tahiti-San Francisco...	Jan. 4–Feb. 19	0.5 W to 0.8 E	0.4 W to 0.9 E	0.6 N to 1.5 S	+3 to −6
San Francisco-Honolulu	Mar. 29–Apr. 11	0.8 W to 0.1 E	0.7 W to 0.2 E	0.1 N to 1.1 S	0 to −3
Honolulu-Apia........	Apr. 29–Jun. 29	1.0 W to 1.1 E	0.8 W to 1.0 E	0.3 N to 1.5 S	0 to −6
Apia-Balboa..........	Jul. 26–Oct. 7	0.5 W to 0.9 E	0.5 W to 0.7 E	1.8 N to 0.7 S	+9 to −1
Balboa-Washington...	Oct. 20–Nov. 10	0.6 W to 1.2 E	0.6 W to 0.8 E	1.8 N to 0.1 N	+7 to −2

[1] Units of third decimal C. G. S.

Preliminary average annual changes of the magnetic elements in the Indian and Pacific Oceans, 1905 to 1920. J. P. Ault.

The average annual changes in the values of the magnetic elements given in tables 2 and 3 were obtained by using the results of observations made on the *Carnegie* and the *Galilee* in the vicinity of the intersections of their various tracks. The magnitude of the change in declination over the southern part of the Indian Ocean is especially worthy of attention. The method employed in computing the tables is the same as that used in discussing the average annual changes for the southern Atlantic.[1] The charts referred to are U. S. H. O. No. 2406 for 1920 and B. A. No. 2598 for 1917.

TABLE 2.—*Preliminary average annual changes for the Indian Ocean.*

Lat.	Long. east of Gr.	Approximate dates showing time-intervals.	Average annual changes.			No. of values utilized.	Annual change in declination.			
							Chart values.		Chart corrections.	
			D	I	H[1]		U. S.	B. A.	U. S.	B. A.
°	°		′	′			′	′	′	′
11.6 N	58.9	1911.7–1920.5	1 W	......	......	3 and 6	1 E	2 E	2 W	3 W
11.2 N	58.8	1911.7–1920.5	......	1 N	+ 4	2 and 2	......	......	......	......
11.6 N	62.9	1911.7–1920.5	3 W	......	......	2 and 2	2 W	1 W	1 W	2 W
11.0 N	66.0	1911.7–1920.5	3 W	......	......	3 and 2	2 W	2 W	1 W	1 W
9.6 N	71.0	1911.7–1920.5	5 W	......	......	4 and 4	4 W	4 W	1 W	1 W
9.4 N	71.3	1911.7–1920.5	......	6 N	+ 6	2 and 2	......	......	......	......
7.8 N	75.6	1911.7–1920.5	......	2 N	+ 6	2 and 2	......	......	......	......
6.9 N	79.9	1911.5–1920.5	5 W	3 S	+ 4	AtColombo	7 W	7 W	2 E	2 E
5.0 N	80.3	1911.5–1920.6	5 W	......	......	4 and 4	7 W	7 W	2 E	2 E
5.0 N	80.6	1911.5–1920.6	......	0	+ 4	3 and 2	......	......	......	......
2.4 N	85.2	1911.5–1920.6	6 W	......	......	8 and 3	7 W	8 W	1 E	2 E
2.3 N	85.2	1911.5–1920.6	......	3 S	+ 5	7 and 2	......	......	......	......
24.3 S	65.7	1911.6–1920.4	14 W	......	......	2 and 3	6 W	7 W	8 W	7 W
24.3 S	66.2	1911.6–1920.4	......	1 N	− 1	2 and 2	......	......	......	......
26.7 S	77.4	1911.4–1920.6	17 W	......	......	2 and 7	12 W	12 W	5 W	5 W
27.0 S	77.2	1911.4–1920.6	......	3 S	− 4	2 and 3	......	......	......	......
33.5 S	77.7	1911.4–1920.6	21 W	......	......	3 and 4	13 W	14 W	8 W	7 W
33.9 S	77.8	1911.4–1920.6	......	0	0	2 and 2	......	......	......	......
35.5 S	92.7	1911.9–1916.1	13 W	......	......	2 and 3	14 W	13 W	1 E	0
36.1 S	97.4	1916.1–1920.6	13 W	......	......	5 and 2	11 W	10 W	2 W	3 W
36.2 S	97.4	1911.9–1916.1	......	1 S	− 8	3 and 3	......	......	......	......
36.2 S	97.4	1916.1–1920.6	......	3 S	− 3	3 and 2	......	......	......	......
39.2 S	29.1	1911.3–1920.4	......	3 S	− 8	2 and 3	......	......	......	......
39.4 S	28.8	1911.3–1920.4	12 E	......	......	3 and 4	9 E	11 E	3 E	1 E

[1] Units of fourth decimal C. G. S.

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[1] See Annual Report of the Director of the Department of Terrestrial Magnetism, Year Book of the Carnegie Institution of Washington for the year 1920, pp. 310–312.

TABLE 3.—*Preliminary average annual changes for the Pacific Ocean.*

Lat.	Long. east of G.	Approximate dates showing time-intervals.	Average annual changes.			No. of values utilized.	Annual change in declination.			
							Chart values.		Chart corrections.	
			D	I	H[1]		U. S.	B. A.	U. S.	B. A.
°	°		′	′			′	′	′	′
39.6 N	231.2	1906.8–1916.7	......	1 S	− 1	2 and 3	......	......	......	......
39.3 N	231.1	1906.8–1916.7	3 E	......	......	2 and 2	2 E	4 E	1 E	1 W
39.1 N	230.7	1916.7–1921.1	2 W	......	......	2 and 6	2 E	4 E	4 W	6 W
39.1 N	231.1	1906.8–1921.1	......	1 S	0	2 and 4	......	......	......	......
38.9 N	231.6	1916.7–1921.1	......	2 S	+ 1	3 and 4	......	......	......	......
38.6 N	232.0	1906.8–1921.1	2 E	......	......	2 and 6	2 E	4 E	0	2 W
38.5 N	194.8	1915.5–1921.1	......	3 N	− 4	2 and 2	......	......	......	......
38.4 N	195.1	1915.5–1921.1	4 W	......	......	2 and 5	1 W	1 W	3 W	3 W
38.2 N	222.6	1907.6–1921.1	......	1 N	− 2	2 and 5	......	......	......	......
38.1 N	223.3	1907.6–1921.1	2 E	......	......	2 and 8	1 E	3 E	1 E	1 W
35.4 N	235.7	1916.8–1921.2	2 W	......	......	4 and 5	2 E	4 E	4 W	6 W
34.8 N	235.5	1905.9–1921.2	3 E	......	......	2 and 4	2 E	4 E	1 E	1 W
34.7 N	236.2	1905.9–1916.8	5 E	......	......	2 and 5	2 E	4 E	3 E	1 E
34.6 N	236.2	1905.9–1916.8	......	2 S	− 3	3 and 3	......	......	......	......
33.4 N	217.2	1907.6–1921.4	1 E	......	......	3 and 6	2 E	3 E	1 W	2 W
33.4 N	217.4	1907.6–1921.4	......	1 S	− 4	3 and 3	......	......	......	......
33.0 N	198.7	1915.5–1921.3	......	3 N	− 6	2 and 2	......	......	......	......
32.7 N	198.8	1915.5–1921.3	3 E	......	......	2 and 4	1 E	1 E	2 E	2 E
29.3 N	223.8	1908.4–1921.2	4 E	......	......	2 and 5	2 E	4 E	2 E	0
29.0 N	197.7	1905.9–1915.5	......	3 S	− 1	2 and 2	......	......	......	......
29.0 N	197.9	1905.9–1915.5	2 E	......	......	4 and 5	2 E	1 E	0	1 E
28.9 N	198.3	1915.5–1921.3	2 E	......	......	5 and 4	2 E	1 E	0	1 E
28.9 N	224.8	1908.4–1921.2	......	1 S	− 2	3 and 4	......	......	......	......
28.8 N	198.2	1915.5–1921.3	......	1 N	− 1	2 and 2	......	......	......	......
28.7 N	197.1	1905.9–1921.3	......	1 S	− 1	2 and 2	......	......	......	......
28.6 N	223.0	1908.4–1921.4	3 E	......	......	2 and 5	2 E	4 E	1 E	1 W
28.5 N	197.3	1905.9–1921.3	2 E	......	......	4 and 4	2 E	1 E	0	1 E
28.5 N	223.8	1905.7–1908.4	......	1 S	− 1	3 and 3	......	......	......	......
28.1 N	224.3	1906.2–1908.4	3 E	......	......	3 and 2	2 E	4 E	1 E	1 W
27.7 N	224.2	1905.7–1921.2	......	1 S	− 2	3 and 3	......	......	......	......
27.3 N	224.4	1906.2–1908.4	......	......	− 2	3 and 3	......	......	......	......
27.2 N	223.3	1908.4–1921.4	......	1 N	− 4	3 and 4	......	......	......	......
26.5 N	224.8	1906.2–1921.1	......	2 N	− 2	3 and 4	......	......	......	......
26.4 N	224.9	1906.2–1921.2	4 E	......	......	3 and 5	2 E	4 E	2 E	0
26.0 N	222.6	1905.7–1921.4	......	1 N	− 3	3 and 4	......	......	......	......
25.8 N	224.0	1906.2–1921.4	3 E	......	......	3 and 5	2 E	4 E	1 E	1 W
25.6 N	217.1	1905.7–1921.3	3 E	......	......	3 and 5	2 E	4 E	1 E	1 W
25.6 N	217.1	1905.7–1921.3	......	2 S	− 2	2 and 2	......	......	......	......
25.4 N	199.3	1915.5–1921.3	3 E	......	......	2 and 2	2 E	1 E	1 E	2 E
25.3 N	199.9	1905.8–1915.5	2 E	......	......	3 and 2	2 E	1 E	0	1 E
25.0 N	199.4	1905.8–1921.3	2 E	......	......	3 and 2	2 E	1 E	0	1 E
24.8 N	223.3	1906.2–1921.4	......	3 N	− 3	3 and 4	......	......	......	......
23.9 N	192.1	1905.8–1921.1	......	6 S	− 1	3 and 2	......	......	......	......
23.6 N	192.0	1905.8–1921.1	4 E	......	......	7 and 4	0	0	4 E	4 E
23.2 N	209.7	1905.7–1921.3	2 E	......	......	2 and 5	2 E	3 E	0	1 W
22.2 N	202.7	1907.7–1921.3	......	4 S	− 2	3 and 3	......	......	......	......
22.2 N	202.8	1905.8–1921.3	......	5 S	− 1	6 and 3	......	......	......	......
22.1 N	202.6	1907.7–1921.3	2 E	......	......	3 and 5	2 E	2 E	0	0
22.0 N	202.0	1905.8–1907.7	......	7 S	+ 3	6 and 3	......	......	......	......
22.0 N	202.7	1905.8–1921.3	3 E	......	......	10 and 5	2 E	2 E	1 E	1 E

TABLE 3.—*Preliminary average annual changes for the Pacific Ocean*—Continued.

Lat.	Long. east of G.	Approximate dates showing time-intervals.	Average annual changes.			No. of values utilized.	Annual change in declination.			
							Chart values.		Chart corrections.	
			D	I	H[1]		U. S.	B. A.	U. S.	B. A.
°	°		′	′			′	′	′	′
22.0 N	203.3	1915.4–1921.3	2 E	......	......	8 and 5	2 E	2 E	0	0
22.0 N	203.4	1915.4–1921.3	......	5 S	− 2	4 and 3	......	......	....	....
21.8 N	202.5	1905.8–1915.4	......	5 S	− 1	6 and 4	......	......	....	....
21.8 N	202.6	1907.7–1915.4	......	4 S	− 1	3 and 4	......	......	....	....
21.8 N	202.7	1907.7–1915.4	2 E	......	......	3 and 8	2 E	2 E	0	0
21.6 N	202.7	1905.8–1915.4	4 E	......	......	10 and 8	2 E	2 E	2 E	2 E
17.9 N	226.4	1915.4–1921.4	1 E	......	......	6 and 6	3 E	4 E	2 W	3 W
17.8 N	226.4	1915.4–1921.4	......	1 S	− 5	3 and 3	......	......	....	....
4.0 N	201.4	1906.0–1921.0	2 E	......	......	9 and 6	2 E	2 E	0	0
3.9 N	201.6	1906.0–1921.0	......	6 S	− 2	7 and 3	......	......	....	....
16.8 S	210.6	1912.7–1921.0	3 E	......	......	5 and 3	4 E	4 E	1 W	1 W
27.8 S	222.9	1912.6–1917.0	4 E	......	......	4 and 3	3 E	4 E	1 E	0
27.8 S	222.9	1917.0–1921.0	2 W	......	......	3 and 5	3 E	4 E	5 W	6 W
27.8 S	222.9	1912.6–1921.0	2 E	......	......	4 and 5	3 E	4 E	1 W	2 W
27.8 S	223.2	1912.6–1921.0	......	3 N	− 1	4 and 2	......	......	....	....
37.1 S	224.6	1912.8–1920.9	......	2 N	− 1	2 and 2	......	......	....	....
37.2 S	224.0	1912.8–1920.9	4 E	......	......	4 and 4	3 E	4 E	1 E	0
38.4 S	221.0	1917.1–1920.9	1 W	......	......	5 and 2	3 E	4 E	4 W	5 W
43.3 S	212.9	1908.1–1920.9	......	2 S	− 2	2 and 3	......	......	....	....
44.8 S	126.2	1916.2–1920.8	......	6 N	0	4 and 2	......	......	....	....
45.1 S	172.1	1916.2–1920.8	2 E	......	......	5 and 4	1 E	1 E	1 E	1 E
45.1 S	172.2	1916.2–1920.8	......	1 N	− 4	2 and 2	......	......	....	....
47.1 S	131.2	1916.2–1920.8	13 W	......	......	5 and 2	2 W	5 W	11 W	8 W
47.7 S	167.0	1916.2–1920.8	......	1 N	+ 1	2 and 2	......	......	....	....
47.8 S	166.8	1916.2–1920.8	5 E	......	......	4 and 5	1 E	0	4 E	5 E
47.9 S	132.4	1916.2–1920.8	......	3 N	0	2 and 2	......	......	....	....

[1] Units of fourth decimal C. G. S.

Molecular and cosmical magnetism. S. J. Barnett. Nature, vol. 107, pp. 8–9 (Mar. 3, 1921).

This article, written in reply to one by S. Chapman, shows that the theory proposed by him of the magnetic effects produced by rotation is essentially identical with that of the author; it extends this theory to some particular cases, and discusses the application of the theory to cosmical magnetism.

The electron theory of magnetism. S. J. Barnett. Science, n. s., vol. 53, pp. 465–475 (May 20, 1921).

This is a general account of the electron theory of magnetism, developed by W. Weber and numerous followers from the theory of Ampère proposed a century ago. Weber's theory of diamagnetism, as originated in 1852 and as slightly modified by Langevin in 1905, is given in some detail. Other theories of diamagnetism proposed by J. J. Thomson, Voigt, Lorentz, and others are then discussed. Langevin's theory of paramagnetism, which, while not an electron theory, is of great importance in connection with such theories, is given in some detail; and the work of Voigt and J. J. Thomson on the diamagnetic and paramagnetic effects of free electron orbits are discussed. The work of Voigt and others on the behavior in a magnetic field of magnetic elements, or magnetons, consisting of homogeneous charged solids or symmetrical electron systems in rotation, is taken up, and some of the most important results of Voigt are given in detail. Considerable space is given to a general theory recently proposed by Gans to account for both diamagnetism and paramagnetism at both ordinary and extreme temperatures, and in both weak and strong magnetic fields; and mention is made, with critical comments, of a general theory proposed by Honda and Okubo, and of various attempts to apply the quantum theory to paramagnetism. The paper next deals with the recent direct experimental evidence obtained by the author and Mrs. Barnett, and later and to a more limited extent by Einstein and deHaas, J. Q. Stewart, and E. Beck, on the nature of the magneton. The theory involved in this work is briefly given, together with its application to cosmical magnetism.

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[1] Abstract of a paper read as a part of the symposium on "Recent Progress in Magnetism," held at the joint meeting of the American Association for the Advancement of Science, Section B, and the American Physical Society, Dec. 1920.

A sine galvanometer for determining in absolute measure the horizontal intensity of the Earth's magnetic field.[1] S. J. Barnett.

After a brief historical statement with reference to the measurement of the horizontal intensity of the Earth's magnetic field by electrical methods, and a general description of sine and tangent galvanometers, with the suggestion of an improvement in the latter, a detailed description is given of a new sine galvanometer, constructed, except for certain details, in the instrument shop of the Department of Terrestrial Magnetism.

The base of the instrument, including the tripod, circles, etc., was taken from one of Wild's theodolites, constructed by Edelmann, and was much improved by the substitution of non-magnetic parts for parts too magnetic, and by the substitution of electrical illumination of the precision circle for daylight illumination by mirrors.

The magnetometer-box is of pure copper, the damping being chiefly electromagnetic. The magnet-mirror is a fine disk of chrome steel with optically flat and parallel surfaces, being in fact one of the gages made by the Bureau of Standards. The torsion tube and head are similar to those of the C. I. W. magnetometers designed and constructed by the Department. A suspension of phosphor-bronze strip with torsional constant 0.001 is generally used. The telescope, which is small but powerful, and the scale, ruled to thirds of millimeter, on white pyralin, are provided with all necessary adjustments. The period of the magnet and the damping, which is adjustable, are such that readings require only a few seconds.

The arrangement of coils is approximately that due to Helmholtz. The spool was machined from white Carara marble impregnated with paraffin at a temperature near its boiling-point. The coils were wound under tension in a single layer in spiral grooves cut with a carbon diamond tool. The wire is pure copper, especially prepared by the Research Laboratory of the General Electric Company. Each coil is wound in two halves and contains 10 turns with a diameter of approximately 30 cm. and a pitch of approximately 2 mm. The two halves start from the same horizontal plane,180 degrees apart, so that the distance between centers of adjacent wires is approximately 1 mm.

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[1] Abstract of a paper to be published in full as a special report in Vol. IV, Researches of the Department of Terrestrial Magnetism, Carnegie Institution of Washington Publication No. 175, Vol. IV, 1921. A preliminary report was presented before the section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, D. C., April 18, 1921.

The axial distance between the centers of the two coils, or the distance between corresponding turns of the spirals, is approximately 15 cm. The insulation resistance between adjacent wires is very high.

The method of measuring the diameters and axial distance of the spiral is described and the results given in tables and curves. The magnetic tests, of three kinds, proving the materials to be satisfactory, are also described.

The theory of the instrument, the method of using it, and the calculation of the error in the constant of the coils due to the construction, as well as of the other errors introduced in the measurement of the horizontal intensity, are given in sufficient detail.

It is shown that the errors in reading the circle and the telescope scale when sufficiently large angles are used, and the error in the constant of the coil, are quite negligible; and that the only other error necessary to consider, viz, that introduced in the measurement of the current traversing the coils, can also be made entirely negligible. In consequence, the horizontal intensity of the Earth's magnetic field can be determined with an error less than 1 part in 10,000, which is all that can be desired.

The instrumental work done in the shop of the Department, chiefly by Mr. G. H. Jung, instrument-maker, is highly satisfactory.

The paper gives a brief statement of the results obtained in two series of simultaneous determinations of the horizontal intensity with the sine galvanometer and standard C. I. W. magnetometer No. 3, Messrs, Fleming, Fisk, Peters, and the author participating in the first series, and Messrs. Fleming, Fisk, and Ives in the second and much more extensive series. The performance of the galvanometer and the agreement between the results obtained with the two instruments have been entirely satisfactory.

On vertical electric currents and the relation between terrestrial magnetism and atmospheric electricity. Louis A. Bauer. Terr. Mag., vol. 25, 145–162 (Dec. 1920).

To what extent the magnetic forces as observed on the surface of the Earth can be referred to a potential is a subject of paramount interest. The solution of the problem is of great importance, both as regards the constitution of the so-called permanent magnetic field of the Earth and the systems giving rise to the manifold variations to which the terrestrial magnetic field is continually subject.

Any electric currents circulating above or below the Earth's surface in concentric layers, i. e., parallel to the surface, will give rise to magnetic forces which may be represented by a potential. Electric currents, on the other hand, cutting the Earth's surface, produce, in general, a mixed magnetic system; the horizontal components of such currents give rise to a magnetic potential, whereas the vertical components cause magnetic forces which can not be referred to a potential. As is well known, the test of the existence of a potential is the vanishing of the line-integral of the magnetic force taken around a closed curve, or circuit, on the Earth's surface. If the line-integral does not vanish and its departure from zero can not be explained by error of observation, or local magnetic disturbances in the region of the circuit, then the existence of a non-potential is revealed; from the magnitude and sign of the integral we may then determine the strength and direction of the electric currents passing perpendicularly through the surface of the region inclosed by the circuit.

It was deemed desirable to make first a reconnaissance and repeat the author's former computations of line-integrals along latitudinal circuits, using this time magnetic charts, which while not representative of all the available data of the Department of Terrestrial Magnetism are close approximations thereto. Line integrals were also computed for various circuits in the United States, as based on the Coast and Geodetic Survey magnetic charts for 1905 and 1915. The general magnitude of the values of the line integrals is such that about 2 to 3 per cent of the Earth's total magnetic field may have to be accounted for by a system of vertical currents. (See also page 314.)

The system of vertical currents, found from the preliminary computations, was such that we apparently have, on the average, negative electricity streaming into the Earth in polar regions, or regions of pronounced polar lights, and streaming out into the air in lower latitudes. Or, we may say also that we apparently have on the average, negative electricity streaming into the Earth in polar regions, and positive electricity streaming into the Earth in lower latitudes. The average resultant current-density for the region of the Earth between the parallels 50° north and 50° south was found to be about $\frac{1}{35}$ of an ampere per square kilometer; from previous investigations the author had found a resultant current-density of about $\frac{1}{30}$ of an ampere per square kilometer. These quantities are about 10,000 times that of the current-density of the vertical conduction-current deduced from atmospheric-electric observations.

Certain qualitative relationships were found to exist between the vertical currents as disclosed by magnetic observations and those obtained from atmospheric-electric observations, but quantitatively, the results from these two sets of observations differ greatly. The results and possible explanations are briefly discussed in the author's next paper, abstracted below.

Measures of the electric and magnetic activity of the Sun and the Earth, and interrelations.[1] Louis A. Bauer. Terr. Mag., vol. 26, 33–68 (March and June 1921).

Evidences of the existence of vertical electric currents, which form an appreciable part of the Earth's permanent magnetic field and its variations, have been multiplying since the publication of the author's paper,[2] "On vertical-electric currents and the relation between terrestrial magnetism and atmospheric electricity." It would seem that several of the perplexing phenomena of atmospheric electricity, e. g., the pronounced geographic variations and peculiar annual variation in the normal potential-gradient and corresponding vertical conduction-current, and the maintenance of the Earth's supposed negative charge, may find their readiest explanation in a system of vertical currents distributed over the Earth in much the same manner as are the currents which result from line integrals of the magnetic force, or of its variations, taken around closed circuits on the Earth's surface.

The paper is divided into the following heads: I, General considerations and remarks; II, Measure of the Sun's activity; III, Measure of the Earth's magnetic activity; and IV, Relations between solar activity and the Earth's magnetic and electric activity. In No. I a general statement of the various problems is made and tentative hypotheses, to be subjected to tests, are advanced in explanation of some of the Earth's magnetic and electric phenomena. The chief results obtained with the aid of the measures derived in sections Nos. II and III are summarized in No. IV and various graphs are given. (See also abstract, p. 350.)

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[1] Abstract of the following papers: On measures of the Earth's magnetic and electric activity and correlations with solar activity, presented before the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, at the annual meeting, Washington, D. C., April 18, 1921; Further investigations concerning the relations between terrestrial magnetism, terrestrial electricity, and solar activity, presented at the general meeting of the American Philosophical Society, Philadelphia, April 23, 1921; New relations between terrestrial magnetism, terrestrial electricity, and solar activity, presented before the Philosophical Society of Washington, May 21, 1921.

[2] See abstract, pp. 347-348.

Instead of using the sun-spot numbers direct for comparison with magnetic and electric variations, it is found (No. II) that a more satisfactory measure of solar radiations and emanations affecting the Earth's magnetic and electric conditions may be based upon the solar-rotation range of sun-spot frequency, or upon some quantity indicative of the rate of change, or variability of sun-spottedness during the Sun's rotation. It is found, in general, sufficient to use for this purpose a series of monthly numbers which represent the average departures of the daily sun-spot numbers from their respective monthly means, regardless of sign. As a first attempt these numbers are regarded as a measure of the energy expended, or work done, by the Sun during periods of activity of interest here; they are briefly termed the "solar-energy numbers" and are designated by D, to distinguish them from the sun-spot numbers, N. For short periods especially, as for example a month, the solar energy numbers are found decidedly superior to the sun-spot numbers, or other measures of solar activity hitherto used. Further improvement in the measure D may be found possible by taking into account certain types of solar prominences.

A simple and rapidly computed quantity is deduced in No. III which is satisfactory, in general, as a measure of the energy-change, w, experienced by the Earth during a magnetic change, or variation, v. This quantity as a first approximation may be set equal to ϵHv, where H is the horizontal intensity of the observing station, v is the observed magnetic variation, or range in the variation, and ϵ is a numerical factor. The values of w are found so closely similar at stations widely distributed over the Earth that quite satisfactory values for comparison with solar changes, for example, may be obtained at a single magnetic observatory situated in moderate latitudes.

Regarding some of the results obtained under the heading "Solar Activity," see abstract on page 350. The chief magnetic and electric results obtained were as follows:

a. The Earth's magnetic energy and average intensity of magnetization, as well as the strength of the normal electric currents circulating in the Earth's crust, suffer a diminution during increased solar activity. The electric currents induced in the Earth during periods of increased solar activity are in general reversed in direction to the normal currents, the strength of these superposed currents increasing with increased solar activity.

b. The diurnal range of the strength of earth-currents, as in the case of the diurnal ranges of the Earth's magnetic elements, increases with increased solar activity; at time of maximum activity the range, as shown by the observations at the Observatorio del Ebro, Tortosa, Spain, 1910–1919, was about 50 per cent *higher* than during the time of minimum solar activity.

c. The magnetic effect running a concomitant course with the solar-activity cycle is retarded, on the average, about one year, so that there is a residual, or an acyclic, effect at the end of the cycle. The actual amount of retardation, in general, increases with intensity of the Sun's activity or energy. This lag in the magnetic effect may be accounted for by the fact that the electric currents generated inside the Earth during magnetic storms and magnetic variations continue for some time after the apparent cessation or diminution of solar activity, or after the period of the variation experienced. The same lag is shown by polar-light frequencies at times of maximum solar activity.

d. On fine-weather or electrically calm days the atmospheric potential-gradient, or the deduced negative charge on the surface of the Earth, increases with increased solar activity, the range in the variation between minimum and maximum solar activity being about 20 per cent. The electric conductivity of the atmosphere, on the other hand, shows but little, if any, systematic variation during the solar cycle. Accordingly, since the vertical conduction-current of atmospheric electricity is derived from the product of the potential gradient and the electric conductivity, it is found that this vertical current also increases in strength with increased solar activity. It would thus appear that atmospheric electricity, like terrestrial magnetism, is controlled by cosmic factors. The results derived here may have an important bearing upon theories of atmospheric electricity.

e. The diurnal range of the electric potential-gradient, as deduced from the observations on the electrically calm days made at the Observatorio del Ebro, Tortosa, Spain, 1910–1919, is found to increase with solar activity; the minimum occurred in 1911 and the maximum in 1917, whereas the sun-spot minimum occurred in 1912 and the maximum in 1917. The range between minimum and maximum diurnal range is about 25 per cent. (It appears probable that the fact just stated for the potential-gradient will also be found true for the vertical conduction-current.)

New measures of solar activity and the "Earth-effect."[1] Louis A. Bauer.

Various measures (sun-spot frequencies, sun-spot areas, faculæ, prominences, flocculi, etc.) have been used, with greater or less success, by previous investigators of the relations between solar activity and geophysical phenomena, especially as regards the Earth's magnetic fluctuations. When the comparisons are made for intervals of a year, for example with the aid of annual means, a striking parallelism is, in general, exhibited between solar activity and activity of the Earth's magnetism. If, however, comparisons are attempted for shorter intervals, a month, a week, or a day, then the discordances between the solar curve and the magnetic curve are so pronounced as to have led several eminent investigators to express doubt as to a direct relationship between the two sets of phenomena.

The measures of solar activity most frequently employed in such comparisons are the well-known Wolf-Wolfer relative sun-spot numbers, as they are the most readily available systematic data. The author in his investigations, extending over a period of about 20 years, has tried every measure of solar activity available. As the combined result to date it is found that, in general, the most successful measure of that kind of solar activity, of special interest here, is a quantity indicative of the *amount of variability of sun-spottedness* during a given period. For example, instead of taking the sun-spot numbers direct for comparison with magnetic or electric fluctuations, take the range (R) in the sun-spot numbers per month, or, still better, the average departure (D) of the daily sun-spot numbers from their monthly mean, irrespective of sign. Such R and D measures of solar activity are also being derived from the published Greenwich areas of sun-spots and faculæ, in order to see whether any further improvement may be made. At times our new measures may be usefully supplemented with the aid of prominence-data.

It is also of interest to mention here the following significant result: The D and R measures of solar activity derived first from the Wolfer sun-spot numbers for 1919 and 1920, and second from the series of solar-constant values, obtained by the Smithsonian Institution at Calama, Chile, for the same two years show a very satisfactory general agreement, especially after the first half of 1919, when observational methods for determining the solar-constant values had been improved.

Various slides were exhibited showing close relationships between the new measures of solar activity, terrestrial magnetism, earth-currents, polar lights, and atmospheric electricity, not only year by year, but also month by month.

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[1] Abstract of paper presented before the American Astronomical Society, Middletown, Connecticut, August 30, 1921. See also Terr. Mag., vol. 26, 113–115 (September 1921).

Some new results were set forth concerning an apparent "Earth effect" upon solar activity as discussed by various investigators on the basis of effects observed regarding the asymmetric distribution of sun-spots, faculæ, prominences, etc., over the Sun's disk. It is found that the effect varies during a sun-spot cycle, as also from cycle to cycle, as shown by the following conclusions:

a. A discussion of the sun-spot numbers for the period of 44 years, 1877–1920, indicates the existence of an apparent annual periodicity in sun-spottedness, consisting mainly of a single wave, the minimum occurring about the time (January) when the Earth is nearest to the Sun, and the maximum occurring on the average in July, when the Earth is farthest from the Sun; the average difference between minimum and maximum is found to be about 6 sun-spot numbers for the period 1877–1920.

b. The mean monthly sun-spot numbers for two 70-year periods, 1851–1920 and 1781–1850, show an apparent annual periodicity opposite in phase; for the first period it is of the character described in (*a*), whereas for the second period it is of the reverse character; accordingly, for the 140-year period, 1781–1920, the apparent annual periodicity is almost eliminated. The periods here mentioned also occur in terrestrial magnetism.

In deriving conclusions *a* and *b* all sun-spot numbers throughout a sun-spot cycle were utilized for the entire period of available data. It is apparent, however, from a combined consideration of *a* and *b*, that the annual periodicity in *a* contains other effects than simply those resulting from the revolution of the Earth around the Sun. The synodic period of Jupiter is 13.11 months, and that of Saturn 12.4 months—hence periods differing not greatly from a year. In fact, Dr. T. Royds, of the Kodaikanal Observatory, India, found that prominences were apparently subject to a period of 13$^1/_3$ months.[1] Assuming that the disturbing or superposed effects upon the annual period would be a minimum at times of sun-spot minima, the annual variation of sun-spot activity, or the "Earth effect," was deduced only from the three circum-minimum years, i. e., year before, year of sun-spot minimum, and year after. For the entire period of available sun-spot data (1749–1920), 15 such circum-minimum monthly means of sun-spot numbers could be formed for each month. The following was found:

c. Throughout the period of 172 years the annual variation of sun-spot activity near the years of minima is practically of the same character, and consists mainly of a double wave. On the average, the maximum "Earth effects" occur at the times of the year, near the equinoctial months, when magnetic disturbances and polar lights are most frequent, and the minimum "Earth effects" occur near the solstitial months, when magnetic disturbances and polar lights are least frequent; the average difference between minimum and maximum effect is 3.4 sun-spot numbers for the circum-minimum years of sun-spot activity.

It would appear from these preliminary studies that the Earth, and probably the other planets as well, is sending out into space or returning, by a sort of reflex action, a portion of the electrified particles continually coming from the Sun; as a result, the Earth exerts a small but observable effect on sun-spot activity, the action being apparently electrical in its nature.

The scientific opportunities of the MacMillan Baffin Land Expedition.[2] Louis A. Bauer.

With the achievement of the North and South Geographic Poles by intrepid explorers, attention is now fortunately being drawn to the need of a scientific exploration of the polar regions.

The MacMillan Baffin Land Expedition has a rare opportunity for obtaining data and information which unquestionably will materially assist in the solution of some of the outstanding questions. Penetrating, as it will, to a region near the North Magnetic Pole, it is planned, for a period of 8 to 10 months, to make continuous and systematic observations, pertaining chiefly to the magnetism of the Earth, the electrical and meteorological condition of the atmosphere, and to polar lights. A sledge trip may also be attempted to the locality of the North Magnetic Pole, supposed to be near the western coast of Boothia Felix, during which a systematic magnetic survey of the region may be undertaken.

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[1] Kodaikanal Observatory Bulletin No. XXXIII.

[2] Abstract of remarks made at the farewell dinner tendered the MacMillan Expedition by the Rotary Club of Portland, Maine, June 29, 1921.

The special instrumental appliances and equipment have been furnished the expedition by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and important accessory instruments have been loaned by various government departments—the Weather Bureau, the Signal Corps, the Coast and Geodetic Survey, and the Bureau of Standards. Canadian governmental bureaus have also extended to the expedition cordial cooperation in various ways and have supplied valuable charts and information. The United States Hydrographic Office has contributed a valuable series of charts. The Department of Terrestrial Magnetism has furthermore given two of the members of the Expedition, Messrs. G. D. Howell jr. and R. H. Goddard, special training at Washington in the proposed scientific work to be carried out in accordance with the instructions and program prepared by the Department. The program of scientific work includes provision for simultaneous cooperative work with other stations in northerly latitudes established by various European countries and Canada in conjunction with the Amundsen Arctic Expedition.

The observations of polar lights will be of special interest. Polar explorers have repeatedly given testimony and have recited experiences which would apparently indicate that the polar-light rays, or beams, pass through the atmosphere and come down comparatively close to the Earth's surface. However, many thousand observations made near the north coast of Norway by a photographic method, similar to the one to be used for the first time in the far North by the MacMillan Expedition, clearly indicate that the rays do not get closer to the Earth than about 60 miles, though they may extend from that level upward hundreds of miles. The MacMillan Expedition will be equipped with photographic appliances for investigating the question as to the depth of penetration into our atmosphere of the auroral beams in polar regions and thus it will be able to make a contribution to our knowledge which will undoubtedly help greatly in establishing a rational theory of polar lights.

Latest annual values of the magnetic elements at observatories. J. A. Fleming. Terr. Mag., vol. 25, 179–181 (December 1920).

A compilation of the most recent annual values of the magnetic elements at observatories distributed over the Earth.

The completion of the general magnetic survey of Australia by the Carnegie Institution of Washington. E. Kidson. (Prepared for the meeting of the Australasia Association for the Advancement of Science at Hobart in January 1921; also presented later before the Royal Society of Tasmania.)

This paper was in continuation of one presented by the author at the meeting of the Association held in 1913 at Melbourne, in which the general plan of the survey was explained and some of the earlier results were communicated.[1] The number and distribution of the stations established by the close of the survey in November 1914 must be considered very satisfactory. The lack of facilities for traveling over large areas in the interior prohibited the execution in its entirety of the original plan of securing approximately one station for every 10,000 square miles of territory with a uniform distribution over the continent.

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[1] See "The general magnetic survey of Australia by the Carnegie Institution of Washington," by E. Kidson. Rep. Austral. Assoc. Adv. Sci., Melbourne, vol. 14, 20–23, 1913.

Close upon 600 stations have now been occupied in Australia by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington; the data for about one-half of these have already been published in the "Researches" of the Department, and the present communication gives the results for those stations occupied since 1914, as extracted from the manuscript for Volume IV of the "Researches," now in press. A great part of the work was done by and under the direction of the author, who describes briefly the various field trips and some of the difficulties encountered. Reference is made to the assistance received in the execution of the work from the government officials in each state.

The Carnegie Institution magnetic observatory at Watheroo, Western Australia. E. Kidson. (Prepared for the meeting of the Australasia Association for the Advancement of Science at Hobart in January 1921; also presented later before the Royal Society of Tasmania.)

This paper points out the factors determining the establishment of the Watheroo Magnetic Observatory of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. A brief account is given of the essentials for a site to realize the requirements for the observatory.[1]

The reconnaissance work for selection of the site, carried out during August 1916 to March 1917 by Mr. W. F. Wallis, with the assistance of Mr. W. C. Parkinson, is described. The speed with which the construction work could be done was limited by war-time conditions, by the heavy roads, and by the isolated location. A description of the four buildings thus far built is given. The instrumental equipment for absolute and variation work and the observatory procedure are briefly described.

The magnetograph records were begun on December 31, 1918, and have been continuous since. Plans for the erection of an atmospheric-electric observatory and for the installation of continuous recording instruments for both atmospheric-electric and earth-current work are under way. Mr. Wallis, after completing the construction work and initiating the routine observatory program, was succeeded as observer-in-charge in November 1919 by the author.

Records of earthquakes at Watheroo Magnetic Observatory. E. Kidson. Terr. Mag., vol. 25, 174 (December 1920).

Magnetic disturbances December 4–6, 1920, at Watheroo Observatory. E. Kidson. Terr. Mag., vol. 26, 24 (March–June 1921).

Earthquake and electric-storm records, December 1920 and January 1921, at the Watheroo Magnetic Observatory. E. Kidson. Terr. Mag., vol. 26, 70 (March–June 1921).

The first of these notes gives detailed circumstances of five earthquakes for which effects were recorded on the magnetograms at the Watheroo Magnetic Observatory during the period November 1919 to September 1920. The third note concerns the earthquake effect extending over 35 minutes of time on December 14, 1920, the record being only in horizontal-intensity trace. During severe thunderstorms in the neighborhood of the Observatory on the afternoon of January 16 and 17, 1921, records of the accompanying electrical effects were made on the magnetograms.

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[1] *Cf.* J. A. Fleming and W. F. Wallis, "The construction and equipment of the Watheroo Magnetic Observatory in Western Australia," *Terr. Mag.*, vol. 25, 1–6, 1920.

Recent results on the diurnal variation of atmospheric electricity from observations aboard the *Carnegie*.[1] S. J. Mauchly. [Abstracts] Phys. Rev. vol. 18, No. 2, pp. 161–162 (1921), and Jour. Wash. Acad. Sci. vol. 11, No. 16, pp. 398–399.

As noted in the various annual reports of the Director of the Department of Terrestrial Magnetism, the atmospheric-electric work aboard the *Carnegie* has since 1915 included observations for determining the diurnal variation of atmospheric electricity.

The first results of such observations were published in 1917[2] and from the limited number of series of observations then available it appeared that the diurnal variation of the potential gradient over the ocean was of the type quite generally observed at land stations, especially in temperate latitudes and in summer, namely, that the curve representing the diurnal variation showed two distinct maxima and two minima, with the greater amplitude ascribed by Fourier analysis to the 12-hour "wave." However, the data upon which this result was based included a considerable proportion of series which could not be continued throughout a full day on account of unfavorable weather. Swann,[3] later, discussing results derived from 20 series made by the observers aboard the *Carnegie*, during the year ending February 20, 1917, with a much greater proportion of complete series at his disposal than for the earlier report, stated that "the afternoon minimum, formerly found about 3 p. m. now appears somewhat later, about 6 p. m., and is less marked than before," and "the effect of the 12-hour Fourier wave is less important in the present curves than in those already published."

In order that the present results should be free from the obvious error which would result from the inclusion of data from incomplete series of observations, the reduction was limited strictly to series which were complete or which required only a small amount of interpolation. On this basis of selection there are available, from the data for July 1915 to February 1921 inclusive, 45 series of potential-gradient observations, each representing a sequence of phenomena which actually occurred during 24 consecutive hours. Of these series, 30 were obtained in the Pacific Ocean, 10 in the Indian, and 5 in the Atlantic; together they represent about half of the Earth's surface.

Separate mean curves were prepared for each of the oceans represented, showing the mean variation of the potential gradient with local time. Comparison of these curves shows: (1) that the observed diurnal variation is due primarily to a single wave of 24-hour period; (2) that the three curves are all similar in form but differ greatly with regard to the phase of the variation for a given local time. For example, the predominating maximum occurs several hours before noon on the Pacific curve, several hours after noon on the Atlantic, and not until after midnight on the Indian.

These phase differences correspond closely enough to the differences between the respective mean longitudes of all positions at which the observations were made in each of the several oceans to suggest the possibility of a simultaneous occurrence of maximum at all places. Since no results of simultaneous ocean observations are available, the material in hand was utilized by referring all observations to Greenwich mean time (civil) and preparing new mean curves for the three oceans on this basis. The results are shown in the accompanying figure.

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[1] Summary of papers read before the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1921; the American Physical Society, April 23, 1921; and the Philosophical Society of Washington, May 21, 1921.

[2] Researches of the Department of Terrestrial Magnetism, Vol. III, pp. 416–420, Washington (1917).

[3] Supplementary report on atmospheric-electric observations made aboard the *Carnegie* from May 17, 1916, to March 2, 1917, by W. F. G. Swann, in "Annual Report of the Director of the Department of Terrestrial Magnetism" for the year 1917, Year Book of the Carnegie Institution of Washington, 1917, p. 282.

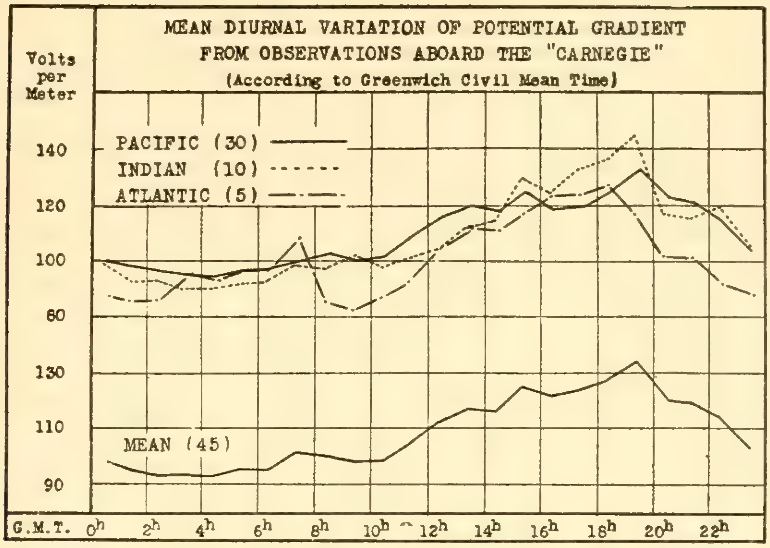

Fig. 1.

From a comparison of these curves it appears that the daily maximum (likewise the minimum) of the potential gradient, over the oceans, occurs approximately simultaneously in all localities. The curve in the lower part of the figure represents the mean diurnal variation of the potential gradient as derived from the entire 45 series. The times of maximum and minimum as given by this curve (7 p. m. and 4 a. m., G. M. T.) probably represent only an approximate yearly average.

However, it is significant to note that (*a*) in western Europe, where local time does not differ greatly from G. M. T., the occurrence of the chief daily minimum at approximately 4 a. m. is common to many stations; (*b*) the diurnal variation of the potential gradient as observed at practically all high-latitude stations and, in winter, at various stations in temperate latitudes, is very similar to what has here been found for the ocean, when differences in local time are taken into account. It is also significant that Mache and v. Schweidler[1] long ago called attention to the fact that only the phase angle of the 12-hour Fourier wave has roughly the same value for most stations, whereas the phase angle corresponding to the 24-hour wave varies greatly from station to station.

A fact of considerable interest is that the diurnal-variation curves for the potential gradient derived from the *Carnegie* observations are very similar to curves which represent the diurnal frequencies of the aurora borealis, as observed at several European stations, and also to curves representing the diurnal distribution of certain classes of magnetic disturbances, when all are referred to the same time-basis. It may also be pointed out that owing to the non-coincidence of the Earth's magnetic axis with its axis of rotation, the time of daily potential gradient maximum, as indicated by the ocean curves, corresponds approximately to the time when the Earth's north magnetic pole, for example, is nearest to the Sun, while the daily minimum occurs, in a general way, when this pole is farthest from the Sun. The actual times of maximum and minimum, however, appear to depend upon the positions of *both* magnetic poles and the fact that their longitude difference is not 180°. These correlations appear to support the assumptions of various investigators that the Earth's electric charge and resultant field may be very intimately related to an electric radiation from the Sun.

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[1] H. Mache und E. v. Schweidler, Die Atmosphärische Elektrizität, p. 27, Braunschweig, 1909.

Although the *Carnegie* has obtained more diurnal-variation data regarding the potential gradient than for other elements, reductions of the available data for positive ionic content (n_+), and conductivity due to positive ions (λ_+), and the positive vertical current-density (i_+) have also been made. For example, the mean curves from 37 practically complete series for n_+ show for the Atlantic, Pacific, and Indian Oceans a consistent diurnal variation with local time, day values being in general above and night values below the mean-of-day value. This is in agreement with the results given in Volume III of the "Researches of the Department of Terrestrial Magnetism" (l. c.) and in the Director's annual report for 1917 (l. c.).

Observations for the diurnal variation of λ_+ were not begun until 1918; consequently, fewer series are available than for the other elements. However, reductions based on 20 series indicate for each ocean a diurnal variation of λ_+ similar to though somewhat less regular than that found for n_+. The range of this variation is of the order of 10 per cent of the mean-of-day value.

Since the diurnal-variation observations for λ_+ were not begun until 1918, the number of series which provide data for both potential gradient and λ_+ are necessarily limited. Nevertheless, from 19 such series we have some interesting preliminary evidence regarding the probable diurnal variation of i_+, the product of practically simultaneous values λ_+ and potential gradient. Since the potential gradient has, over the ocean, a well-defined variation according to universal time, and λ_+ only a weak variation on a local-time basis, we should expect the diurnal variation of i_+ to resemble most nearly that of the potential-gradient. This, in fact, is what we find, and while the limited data available will not justify complete confidence in the result, it is significant that the separate mean curves for the three oceans are in good agreement with each other, both as to the mean-of-day values of i_+ and in showing a well-marked diurnal variation, whose chief component progresses roughly according to universal time. The results, so far as they go, give no evidence whatever which would indicate an automatic adjustment between potential gradient and conductivity, such as to maintain a practically constant vertical-current density.

Briefly summarized, the reductions of the data available to date from diurnal-variation observations made aboard the *Carnegie* indicate the following preliminary results:

(*a*) For the potential gradient, a marked diurnal variation whose chief component over the major portion of the Earth is a wave of 24-hour period which occurs approximately simultaneously in all localities.

(*b*) For n_+ and λ_+ a weak diurnal variation according to local time, both quantities being, on the average, greater during the day than during the night.

(*c*) For i_+, the product of λ_+ and potential gradient, a well-defined diurnal variation which is approximately similar to that noted under (*a*) for the potential gradient.

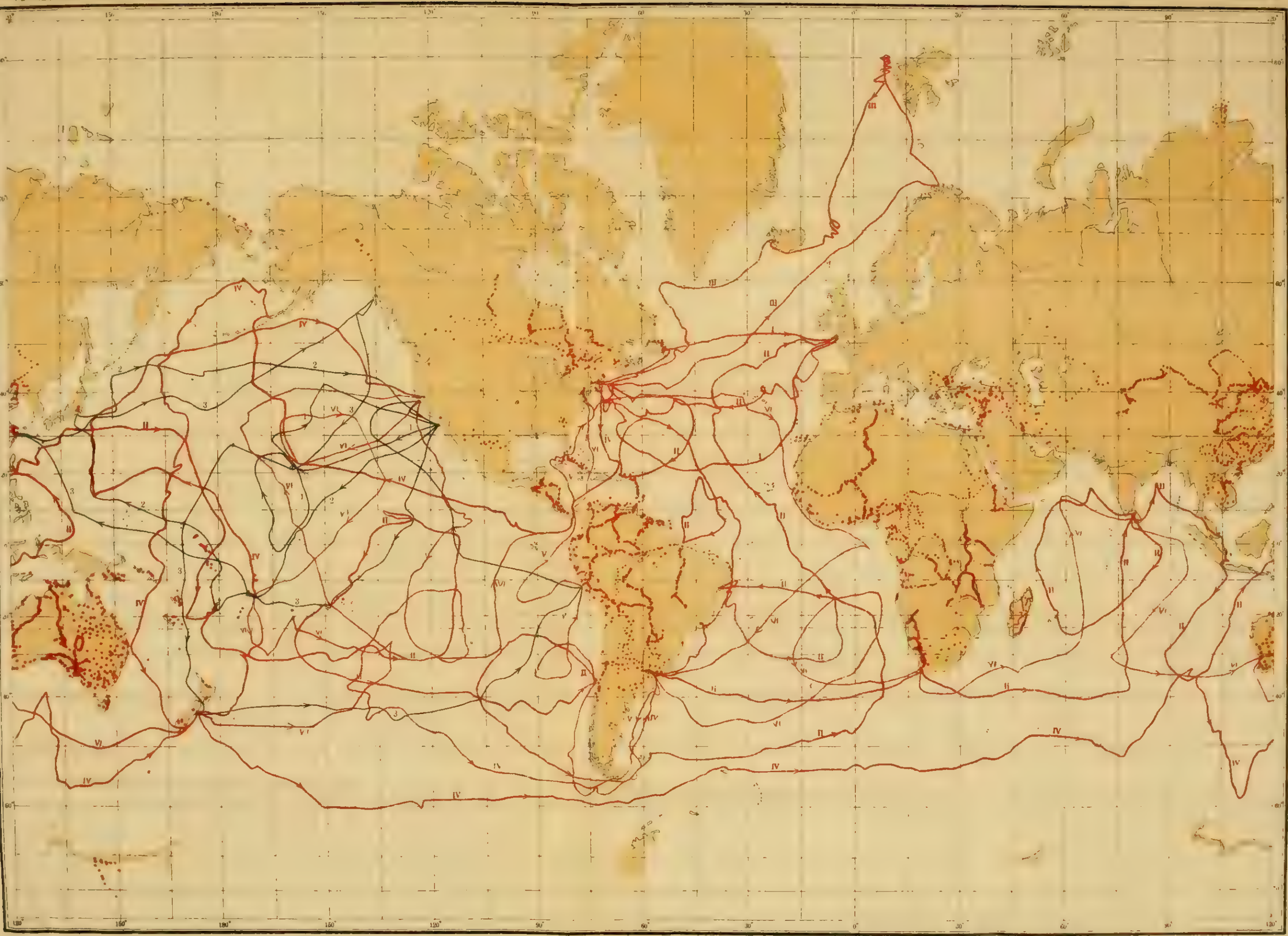
The full publication of the observational data and discussion of results will be deferred until after the completion of the present cruise of the *Carnegie.*

The magnetic storm of May 13–17, 1921, at the Watheroo Observatory, Australia. W. C. Parkinson. Terr. Mag., vol. 26, 26–28 (March–June 1921).

This paper describes in detail some of the features of the unusual magnetic storm of May 13–17, 1921, as recorded on the magnetograms at the Watheroo Magnetic Observatory. Much of the magnetic record was lost on account of the severity of the disturbance which carried the trace off the recording sheet. The commencement in all three elements was very sudden at $21^h\ 09^m$ (120th east meridian standard time) on May 13, with an almost immediate increase in horizontal intensity, H, of about 70γ and decrease in vertical intensity, Z, of about 27γ. The rapid and violent movements in all elements during the 4 days are described. At about 10^h on May 15 the H magnet was found hard against the stops and, after being deflected back by a small magnet, returned at once to the stops. The registering spot could only be made to stay on the sheet by turning the torsion head. The torsion head was restored to the original reading at $19^h\ 24^m$ on the same day, but at 16^h on May 16 the magnet was again found against the stops and was again brought back by the torsion head. Following this for the next 8 hours the short-period fluctuations were absent, but on May 17 after midnight until 16^h the movements were of moderately short period and limited range until normal conditions returned.

On the evening of May 16 there was what might have been a fine display of *aurora australis* but for a bright moon and some clouds. Various striking features were noted, some being visible as much as 15° above the horizon. The appearances were, in general, of short duration.

According to a letter of the Deputy Postmaster-General of Western Australia, there were on May 14, 15, and 16, earth-currents showing on the government telegraph lines of Western Australia and of South Australia.



Map showing the Magnetic-Survey Work of the Department of Terrestrial Magnetism during the Period 1905–1921 (November).

(Black lines show the cruises of the *Galilee* and red ones, those of the *Carnegie*. Red dots show the land stations.)

ARCHÆOLOGY.

Morley, Sylvanus G., Santa Fé, New Mexico. *Associate in American Archæology.* (For previous reports see Year Books Nos. 13–19.)

The Central American Expedition for 1921 sailed from New Orleans for Puerto Barrios, Guatemala, on January 7, remaining in the field for five months. The staff consisted of Dr. Morley, Dr. Carl E. Guthe, Mr. William Gates, Mr. O. G. Ricketson jr., and Mr. A. K. Rutherford.

Owing to this increase in personnel over that of former years, it was possible not only to cover more territory than in any previous season, but also to enlarge the field of investigation, thus adding excavation proper and a first-hand study of the Maya linguistic problem to the usual exploratory work of the Institution in this region.

The activities of the year may be classified and described under three headings as follows:

1. The further exploration of northern Peten in search of archæological sites and hieroglyphic inscriptions by Dr. Morley. (6th season.)
2. The excavation of Tayasal, the last independent Maya capital, on an island in the lake of Peten Itza in northern central Peten by Dr. Guthe. (New.)
3. A study of the Maya dialects spoken at the present time in northern British Honduras and in the Department of El Quiche in the highlands of Guatemala by Mr. Gates. (New.)

After a preliminary trip to Guatemala City to notify the Ministry of Foreign Relations that the Carnegie Institution was prepared to begin operations under the permit granted to it in June 1920 by the Government of Guatemala for exploration and excavation in the Department of Peten,[1] Dr. Morley returned to Belize, where he was met by Messrs. Ricketson and Rutherford, and thence proceeded by motor-boat up the Belize River to El Cayo on the frontier of British Honduras, where a mule-train was secured for the journey into the interior of Peten.

The exploratory work of the year was divided into three trips: The first from February 7 to March 6 in northeastern Peten to the ruins of Xultun, Uaxactun, and Nakum; the second from March 23 to April 11, in northern central Peten, to the ruins of Benque Viejo, Naranjo, El Encanto, Tikal, Uolantan (new), Ixlu (new), and Tayasal; and the third from April 22 to June 1 in northwestern Peten to the ruins of Itsimte and Piedras Negras.

The new material discovered during these three trips may be briefly summarized as follows:

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[1] See Year Book No. 19, p. 324.

1. Two new sites, Uolantun,[1] four miles south of Tikal in northern central Peten, and Ixlu[2] at the western end of Lake Peten Itza.
2. Seventeen new Initial Series.
3. Twenty-one new monuments.[3]
4. Thirty newly deciphered dates.[4]

The seventeen new Initial Series are:

Site.	Monument.	Maya date.	Christian era.
Xultun	Stela 5	9.12. 0. 0. 0	413 A. D.
Xultun	Stela 6	9. 3. 7. 0. 0	242 A. D.
Xultun	Stela 11	9. 5. 7. 0. 0	282 A. D.
Xultun	Stela 21	9.14.10. 0. 0 (?)	462 A. D.
Naranjo	Stela 25	8. 5.18. 4. 0	100 B. C.
Tikal	Stela 6	9. 4. 0. 0. 0	255 A. D.
Tikal	Stela 15	9. 3. 0. 0. 0	235 A. D.
Uolantun	Stela 1	8.18.13. 5.11	150 A. D.
Piedras Niegras	Stela 23	9.16.10. 0. 0 (?)	502 A. D.
Piedras Niegras	Stela 26	9. 9.15. 0. 0	368 A. D.
Piedras Niegras	Stela 30	9. 5. 0. 0. 0	275 A. D.
Piedras Niegras	Stela 32	9.10.15. 0. 0 (?)	388 A. D.
Piedras Niegras	Stela 34	9.10.19. 5. 9 (?)	392 A. D.
Piedras Niegras	Stela 38	9.12.10. 0. 0	423 A. D.
Piedras Niegras	Stela 39	9.12. 5. 0. 0	418 A. D.
Piedras Niegras	Stela 40	9.15.14. 9.13	486 A. D.

NOTE.—Stela 23 has two Initial Series, but one is entirely destroyed except for the Initial Series introducing glyph.

Perhaps the most important discovery of the field season was the decipherment of the Initial Series on Stela 25 at Naranjo as 8.5.18.4.0, which makes it the earliest historical Initial Series yet reported anywhere. (See figure 1*a*.) This early Baktun 8[5] date, although it does not represent the contemporaneous date of this monument,[6] nevertheless antedates the Initial Series on the Tuxtla Statuette

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[1] This Maya word means *uolan*, "something which has been rounded," *tun*, "stone," *uolantun*, "stone which has been rounded." This site was so named because of a unique feature presented by the single monument found there. This monument had been broken in ancient times and the top fragment, a piece 2½ feet long, had been reshaped to serve as a round altar for the larger bottom piece, hence the name "stone which has been rounded."

[2] Ixlu is the Maya word for a certain fish found in Lake Peten Itza, after which the arroyo running into the eastern end of the lake is named. As this second site is just north of the north bank of the Ixlu Arroyo it has been given the same name.

[3] This total includes the two new monuments (a stela and a lintel) found by Dr. Guthe early in April at Tayasal.

[4] This total includes 18 new Period Ending dates, and 12 out of the 17 new Initial Series, the remaining 5 new Initial Series not having been surely deciphered as yet.

[5] Mr. Gates has suggested this word for the 144,000-day period, heretofore known as the cycle. It is composed of the Maya word *bak*, meaning 400, according to Father Maria P. Beltran de Santa Rosa (Arte del idioma Maya, p. 201), and *tun*, the word for the 360-day period. An analogue for this exists in the word for the 7,200-day period, *katun*, generally assumed to be a contraction for *kaltun*, *kal* being the word for twenty. The word *hotun*, which has been suggested for the 1,800-day period, is derived in the same way, *ho* being the Maya for five, and *hotun* five times the *tun* or the 1,800-day period.

[6] The contemporaneous date of Stela 25 at Naranjo is 9.9.0.0.0, 445 years later than the date of its Initial Series, which is still 20 years earlier than the earliest contemporaneous date previously reported at this site, i. e., 9.10.0.0.0 on the reused lintel found in the Hieroglyphic Stairway.

(8.6.2.4.17) by 4 years and that on page 70 of the Dresden Codex (8.6.16.12.17) by 18 years, the two earliest historical Initial Series previously known.

The outstanding importance of this discovery lies in the fact that we may probably interpret it as indicating that the Maya in Baktun 9 still preserved definite traditional knowledge, if not indeed actual contemporaneous historical records, reaching back to the beginning of Baktun 8, four or five centuries earlier.

Of scarcely less importance were the discovery and decipherment of another Baktun 8 Initial Series at Uolantun. (See figure 1*b*.) In the case of this monument, however, its Initial Series (8.18.13.5.11) is the contemporaneous date, which makes it the second oldest Maya monument yet reported, being 81 years later than Stela 9 at Uaxactun and 66 years earlier than the earliest date yet deciphered at Tikal (9.2.0.0.0 on Stela 9).

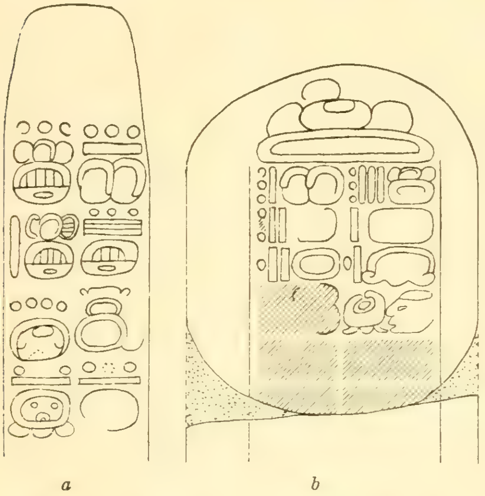

FIG. 1.—Stela 25 at Naranjo. *a*. The inscription on this monument opens with the date 8.5.18.4.0 (100 B. C.) the earliest historical Maya date yet discovered. The contemporaneous date, however, was 445 years later or 345 A. D. *b*. Stela 1 at Uolantun. This monument bears the date of 8.18.13.5.11 (150 A. D.) which makes it the next oldest Maya yet discovered, Stela 9 at Uaxactun antedating it by 80 years. It has been broken into fragments in ancient times and the top fragment was reshaped for use as an altar after it had been broken.

Uaxactun, containing the oldest Maya monument yet reported (8.14.10.13.15 on Stela 9), is 10 miles north of Tikal,[1] and Uolantun is 4 miles south.

In the same vicinity, at El Encanto, 12 miles northeast of Tikal, Dr. R. E. Merwin discovered another early monument in 1910;[2] and although it has been impossible to decipher the date of this, on stylistic grounds it may surely be referred to the early part of Baktun 9.

At Tikal four very early Baktun 9 dates were deciphered this season as follows:

Tikal...Stela 9	9.2.0.0.0	216 A. D.
Tikal...Stela 7	9.3.0.0.0	235 A. D.
Tikal...Stela 15	9.3.0.0.0	235 A. D.
Tikal...Stela 6	9.4.0.0.0	255 A. D.

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[1] See Year Book No. 15, pp. 339, 340.

[2] See Memoirs of the Peabody Museum, Harvard University, Vol. V, No. 3, pl. 53, pp. 152, 163, 194.

Indeed there are only four other undated monuments now known at this site which on stylistic grounds may be earlier: Stelæ 1, 2, 4 and 18. This clustering of the earliest Old Empire monuments, either at or around Tikal, strongly suggests that this was the first part of the Peten region to be occupied by the Maya when they migrated thither from some habitat farther to the west, possibly somewhere along the Gulf coast of Mexico.[1]

These several cities are located at the head of the Holmul Valley, and although much further exploration throughout Peten will be necessary before final conclusions can be drawn, indications now are that the upper reaches of this valley may have been the center of the earliest Maya occupation in the Old Empire region.

Somewhat surprising was the decipherment of two early dates at Xultun, the large city of the second class discovered by the Carnegie Central-American expedition of 1920.[2] That this was a comparatively recent Old Empire site seemed to be indicated by the very late dates deciphered there last year, 10.1.10.0.0 on Stela 3 and 10.3.0.0.0 on Stela 10; also by the failure to find any date earlier than the close of the Middle Period (9.14.0.0.0 on Stela 15[3]), and more particularly by the location of this city, well up in the northeastern corner of Peten directly in the line of migration followed by the Maya northward into Yucatan at the close of the Old Empire.

However, the decipherment of the dates of Stelæ 6 and 11, 9.3.7.0.0 and 9.5.7.0.0 respectively, carries the monumental sequence here back toward the beginning of Baktun 9 and gives a recorded occupation of this site of nearly a baktun (9.3.7.0.0 to 10.3.0.0.0), i. e., for 387 years. The discovery of these two early dates at Xultun indicates that the Maya spread northeastward from around Tikal for a considerable distance at a fairly early date and established themselves in northeastern Peten not very long after they had colonized the Copan region, 200 miles to the southeast.

The new site at the eastern end of Lake Peten Itza, Ixlu, contains five new monuments, viz, two sculptured stelæ, a sculptured altar, and two plain stelæ. The first three date from the very close of the Old Empire, Stela 1 from 10.1.10.0.0 and Stela 2 and the altar from 10.2.10.0.0, and it is obvious that this is a very late site. These two dates exactly alternate by lahuntun intervals (3600-day periods) with the two stelæ found in the modern village of Flores on an island at the extreme western end of the lake, viz:

Flores	Stela 1	10.1.0.0.0	590 A. D.
Ixlu	Stela 1	10.1.10.0.0	600 A. D.
Flores	Stela 2	10.2.0.0.0	610 A. D.
Ixlu	Stela 2	10.2.10.0.0	620 A. D.

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[1] For hypotheses concerning the origin of the Maya civilization see Carnegie Inst. Wash. Pub. No. 219, pp. 402–415.

[2] See Carnegie Inst. Wash. Year Book, No. 19, pp. 322–324.

[3] In the first announcement of the discovery of this site this monument was called Stela 13 (see Year Book No. 19, p. 322). In the revised nomenclature it has been assigned the number 15.

These new monuments are magnificent specimens of Old Empire sculpture; indeed, Stela 2 and its associated altar will rank among the very finest examples of Maya plastic art that have come down to us.

Dr. Guthe's discovery of two inscribed monuments at Tayasal, the last Itza capital (1450–1697 A. D.), was a find of first importance. One is a stela, the other a lintel. Unfortunately, only the base of the former is preserved; enough remains, however, to show that it had been inscribed with a double column of glyphs on the back.

The lintel, although broken, is more nearly complete. It clearly records a Calendar Round date, of which the day is surely 11 Ahau and the month 18 ?, the incomplete month-sign bearing more resemblance to Mac than to any other month-sign. There were no katuns, lahuntuns, or hotuns which ended on the day 11 Ahau 18 Mac during the occupation of Tayasal, but the tun ending 12.5.9.0.0 (1467 A. D.) fell on this date. If the above reading is correct, this lintel must have been carved very shortly after the Itza established themselves at Tayasal; unfortunately, the doubtful identity of the month-sign casts a cloud on its accuracy. In any event, Dr. Guthe's discovery of inscribed monuments at the very beginning of his work justifies the expectation that subsequent excavations will uncover other similar material and shed much light on this final phase of independent Maya history.

The last fortnight of the field season (May 18 to June 1) was spent at Piedras Negras on the Usumacintla River in the westernmost corner of Peten. As already noted, five new monuments and nine new Initial Series were discovered at this site. Scale drawings of all Initial and Supplementary Series were made and a large number of photographs were secured.

The most important contribution here was the filling in of lacunæ in the sequence of the hotun-markers, so that now the corresponding marker for every 1800-day period from 9.10.5.0.0 to 9.18.5.0.0, 33 in all, has been identified. In some cases, as for example, Stelæ 39, 38, and 40, it was even possible to predict what their corresponding dates would be in advance of the actual decipherment of them, because these particular hotun-endings, 9.12.5.0.0, 9.12.10.0.0, and 9.15.15.0.0, respectively had not been represented heretofore in the monumental sequence. These three new monuments were found to record precisely these three dates.

Piedras Negras presents a longer unbroken sequence of hotun-markers than any other Maya city, 33 (165 years) as compared with 14 (60 years) at Quirigua, the next most perfect. This feature, it is anticipated, will greatly assist in the final elucidation of the Supplementary Series, which is a lunar count associated in some as yet undetermined way with eclipse phenomena.

One other discovery at Piedras Negras is worthy of special mention, namely, the finding of a fragment of Stela 30 reused in the roofing of a drain through the platform north of Mound VI. This indicates that Stela 30 had been broken in ancient times, since a piece of it had been built into the roof of a drain before the city had been abandoned. Owing to this sheltered position, its inscription was perfectly preserved and records the date 9.5.0.0.0 (275 A. D.). This date is 75 years older than the earliest date previously reported at this site (9.8.15.0.0 on Stela 25) and carries the foundation of this city at least as far back as the first quarter of Baktun 9.

This pushing back of the monumental remains to the early part of Baktun 9, and even earlier, at a number of sites, Tikal, Xultun, Uolantun, and Piedras Negras, for example, is one of the most significant results of the last field season, and it is confidently anticipated that further exploration, especially in the region around Tikal, will shed much light on the beginnings of the Maya civilization in the Old Empire region.

Report of Dr. Carl E. Guthe.

Dr. Guthe sailed from New Orleans on February 11, 1921. During the latter part of the month a week was spent in excavating a small mound within the borders of British Honduras, at a clearing called "New Boston," 4 miles east of Baker, a village on the banks of the Belize River. After returning to Belize, in order to meet Mr. Gates, Dr. Guthe left on March 7, met the rest of the expedition in El Cayo, British Honduras, and proceeded at once, with Mr. Ricketson, to Flores, Peten, arriving there on March 18. The first two weeks were spent in making a transit survey of the principal plazas of Tayasal. Actual excavation began April 5 and continued until May 21. Dr. Guthe left Flores on May 23, arriving in the United States on June 9.

The excavations at New Boston were made possible through the kind offices of Dr. T. Gann, of Belize, and the officials of the Belize Estate and Produce Company, to whom the land upon which the mounds are situated belongs. The purposes of this excavation were two-fold: to obtain some data upon the construction of mounds in this area and to secure a collection of potsherds from this district.

A mound which consisted almost entirely of large and small stones, with very little earth, was trenched from one side to the center. Two walls of dressed stone, one running at right angles to the other, were uncovered. Neither extended to the surface. The foundation course in both cases was composed of large flat stones which projected beyond the face of the wall proper. A small but representative collection of sherds was secured. The mound also yielded a few fragmentary human bones, a serpentine bead, and some partly finished flint objects. Since flint outcrops are numerous in this district, it is safe to assume that flint-working played an important part in the economic life of the builders of these mounds.

Upon reaching Flores, Dr. Guthe met with instant and hearty coöperation on the part of the government officials under Dr. José Prado Romaña, the Governor of Peten, and of Dr. Robert Boburg, a resident Englishman. Unusual labor conditions and the strange class of work required caused some trouble at the beginning, which was, however, soon regulated.

The early Spanish writers state that the Itzá left their home, Chichen Itzá in northern Yucatan, about the year 1450 and went south, founding a city which they called Tayasal, upon a large island in the lake of Peten Itzá. The purpose of the present expedition was to verify as far as possible the historical and geographical information contained in the early reports of this site,[1] to secure an accurate idea of the plan and extent of the ruins, and to do what preliminary excavations seemed advisable.

Recent archæological investigators in this country have ascertained that this city is now upon a large peninsula which juts into the lake from the east. The present capital of Peten, the little village of Flores, is situated upon a small island within a quarter of a mile of the shores of this peninsula. Through conversations with inhabitants of Flores who knew the surrounding country, and by means of personal observations of the topography and present lake of Peten Itzá, it was possible to explain and clarify, in a most gratifying manner, many of the statements of the early Spanish writers which were obscure or seemed to be actually contradictory. Current place-names were secured for some of the spots mentioned in the early accounts, and the itineraries of the seventeenth century explorers were worked out with a fair degree of accuracy. Copies of three of the early maps of the district were interpreted satisfactorily by a study of the region at first hand.

During Dr. Morley's visit to Flores, careful measurements were made to determine the probable amount of subsidence in the water-level of the lake since the end of the seventeenth century, which made of the then island of Tayasal a promontory. A rock outcrop near the plaza of Flores, with a design incised upon it, is 45 feet above the present water-level. A very distinct line of demarkation on the peninsula itself, between the low jungle growth of the lake-shore and the grasslands which cover the ruins proper, is approximately 40 feet above the present water-level. From this evidence and other corroborative data, it seems probable that 225 years ago the water-level was between 40 to 45 feet higher than at present. There is some contradictory evidence, such as finding potsherds below this former water-level, but the general mass of evidence, including that in the early maps, is overwhelmingly in favor of the figures given.

The civic and religious center of Tayasal, as marked by the larger mounds, occupies the western and highest part of the former island, covering an area about 2 kilometers long, from east to west, by 0.75 kilometer wide. The topography is fairly rugged with numerous outcrops of limestone, causing many and sudden irregularities in the surface. The mounds were placed with due regard to these irregularities, and in some cases use was probably made of natural knolls in their construction. The eastern part of this civic and religious center is lower than the western part, and covered with a dense growth of high underbrush. At the eastern end stands a huge pyramid which commands the entire surrounding country. Another large pyramid marks the western end, which practically coincides with the end of the peninsula itself. The western part is now covered with high grass, which permits the mounds to stand out clearly. In addition to the center of the city, there are, of course, the more outlying districts. Smaller mounds are said to occur as far as 10 kilometers east of the western end of the peninsula.

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[1] History of the Spanish Conquest of Yucatan and of the Itzas, P. A. Means, Peabody Museum Papers, Vol. VII, Cambridge, Massachusetts, 1917.

The highest part of the peninsula, about 0.75 kilometer east of the end of the promontory, is occupied by a well-defined group of mounds surrounding four principal and four subsidiary plazas. A careful transit survey of this group occupied the first two weeks of the work (see fig. 2). The four principal plazas are arranged in line from east to west, each being at a higher level than the one to the east of it (see cross-section at top of fig. 2). The western and highest plaza is the summit of a large pyramid, like an acropolis, which is probably partly natural and partly artificial. The four secondary plazas are arranged around the larger ones in a manner implying consideration of the topography. This group probably marks the very center of the former city's activities. It occupies the very highest part of the peninsula; it is the most closely coördinated group of the city; and within it were found the two hieroglyphic monuments. At the very beginning of the survey, the stub of a stela with traces of hieroglyphs upon it was found approximately in the center of the second highest of the four larger plazas.

Excavations were begun in the plaza in which this stela was found, by uncovering a small, low mound in the plaza itself, just south of the monument and apparently associated with it. When uncovered it proved to be a small square building upon a low platform, with only the foundations of the walls remaining. A space resembling a doorway was left in the middle of each side of these foundations. The masonry was partly of dressed and partly of rough stone. The walls themselves were probably similar to those made in the country to-day, of vertical saplings lashed to horizontal ones and then completely covered with mud or mortar. Two fragments of a lintel were found, one on the mound itself, the other about halfway between the mound and the stela, which Dr. Morley assembled and deciphered as 12.5.9.0.0 11 Ahau 18 Mac (1467 A. D.). During the excavations here six burials, all fully flexed and entirely without furniture, were exposed.

The eastern end of the long mound on the southern side of this same plaza was also cleared; this mound proved to be a terraced substructure. Instead of the regular terracing usually found in Maya architecture, the terraces varied in width, with the walls between differing in heights to an even greater extent. The masonry was not the fine stonework of northern Yucatan, but simply irregular stones, laid in very uneven courses and smoothed over with liberal applications of mortar and mud. Only the lowest wall was composed of dressed stone. The floors, on the other hand, were very fine indeed, presenting a surface nearly as smooth as a cement floor, with a foundation of broken stone several inches thick. On one terrace, at the outer edge, the floor had been raised about 2 centimeters, just enough to prevent the water from a torrential rain running over the side of the terrace and to guide it to a probable outlet. The floors ran underneath the walls, showing clearly that the walls were built after the floors were laid. No trace of a building could be found on the top, unless a few scattered flat stones were the remains of a foundation for a house of wattle and daub. In one section of this uppermost floor there was a distinct depression, where the floor appeared to have sagged because of some heavy weight, such as a wall, resting upon it.

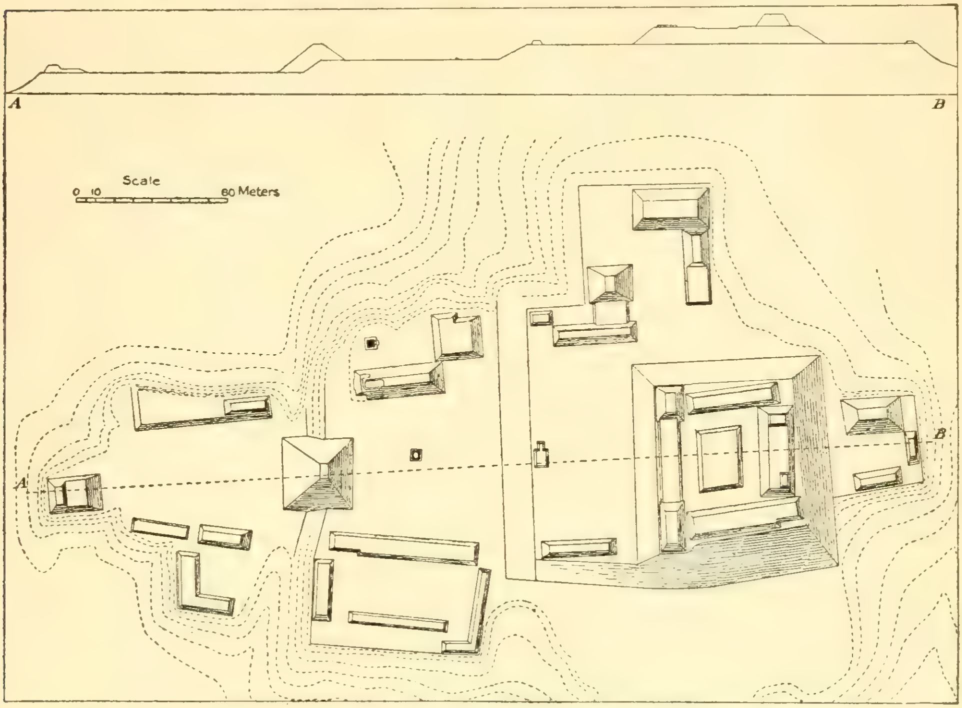

FIG. 2.—Map and cross-section of principal group of mounds and plazas at ancient Itza capital of Tayasal. The section shown was probably the civic and religious center of the city.

A trench was run into the pyramid on the eastern side of the same plaza. The floor of the plaza itself, finished like the other floors, was uncovered, and also the very much ruined face of the pyramid. In this trench, as well as in all others, the stratification was studied carefully in order to ascertain the manner of disintegration of the mounds.

The fourth and last mound on which excavations were undertaken was the small one just south of the main group around this second highest plaza. This mound proved to be a small square building, 3.75 meters on a side, set upon a low platform, 30 centimeters in height, which made a terrace a meter wide on all four sides of the building. On the western side of the building a small steep stairway of eight steps led to the top, which was about 2 meters above the platform. The walls of the building were of unfinished stones, but those of the platform consisted of well-dressed limestone. The interior of the building had been completely filled. Excavations in the center of the mound disclosed, at a depth of 3.5 meters below the top of the building, a tomb of large, rough, flat limestone slabs leaning against one another to form a crude vault. In this tomb was the skeleton of some important personage, laid on its back at full length, with the head towards the north. With the burial were found five unbroken pottery vessels, an obsidian knife, and a necklace composed of eighteen spherical beads of serpentine and jade, and five beads of clay and bone. Although the vessels were somewhat incrusted with lime, it was possible to obtain the designs, in colors, of four of the five. One, cyclindrical in shape, was fluted.

The dearth of smaller objects was very noticeable. In the course of the entire excavations, not a single bone implement was found and less than a dozen stone tools appeared, but potsherds were very common indeed. A large collection was made, showing examples of all of the many variations in shapes and wares. In accordance with the permit granted by the Government of Guatemala, the objects found in the tomb were deposited with the local authorities at Flores.

While excavating for a large cistern near the plaza of Flores, the government exposed several floors, many potsherds, and at least one grave. From this work two complete vessels were saved.

The interest shown by the inhabitants of Flores towards the end of the work was extremely gratifying, in view of the fact that at the beginning there was an atmosphere of tacit disapproval. On Sundays especially, a great many groups climbed the steep path from the lakeshore to inspect the work. The governor and his staff, all of whom had evinced a keen interest from the very beginning of the work, visited the excavations many times. On the eve of departure, Dr. Guthe was informed that the government would install a glass case in the public library in order to exhibit the collection, would place a guard at the excavations to protect the walls and mounds from vandalism, and also place a roof over the tomb to protect it from the weather.

Van Deman, Esther B., Rome, Italy. *Associate in Roman Archæology.* (For previous reports see Year Books Nos. 9–15.)

On account of the uncertain living conditions still existing in Italy, it was deemed inadvisable to resume work there before the spring of 1922. The year has been spent very profitably, however, in great part upon the text of the handbook on Roman Concrete Construction and in the study of a number of problems connected with it for the solution of which the university libraries of America offer special facilities. Among the more important problems to which special attention has been given is that of the historical development of brick and of concrete construction in general and the political and economic conditions leading to or accompanying the various steps in that development in Rome. A careful study has been made of the history of construction in other ancient civilizations, for the sake of comparison as well as to determine, if possible, the people and the period to which the discovery of the use of burned bricks and of concrete is to be assigned. The meagerness of the details concerning construction found in ancient authors and the inaccuracy and unscientific character of the descriptions of the ancient remains in various countries given by the earlier modern travelers and students render the subject one of extreme difficulty. Investigations of a more scientific character, however, have been carried on, in recent years, in certain of the more important centers of ancient culture, among which are Greece, Crete, Egypt, Babylon, and Assyria. As a result, a considerable body of trustworthy evidence concerning the construction of the ancient monuments in these countries is now accessible, though in part as yet unpublished.

An exhaustive review has been undertaken of the periodical literature along the lines involved which has been published since the rise of modern archæological investigation in the early part of the nineteenth century. By this means, a number of important monuments, now wholly or in part destroyed, have been identified.

The first three months of the year were spent in Bermuda. The building-stone used throughout the islands was found to resemble very closely that used in certain parts of Sicily. A study, in leisure hours, of the house and the field walls, especially those built by the early settlers, revealed also many noticeable similarities between their methods of construction and those used in the ancient Sicilian monuments. An interesting, if not unique, example of the use in modern times of the primitive corbelled or pseudo-vault, was found in a group of small, square stone buildings belonging to the earlier period, which were used as butteries.

During the past five years a marked increase has been noted in the recognition by foreign as well as by American archæologists of the working value of the new canon of construction.

BIBLIOGRAPHY.

Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–19.)

The Index Medicus for 1920 (Second Series, Volume XVIII) contains 932 pages, with an index covering 175 pages, as compared with the volume of 984 pages, with index of 183 pages, for 1919. The decrease in size of Volume XVIII (1920) is due to the fact that Volume XVII (1919) contains a large portion of the great backwash of German medical literature which had accumulated during the war period and which did not reach the editors until during 1919-1920. It was decided in 1920 to print future numbers of the Index Medicus (beginning January 1921) in strictly alphabetical order of subject-rubrics in place of the arrangement employed during the period 1879-1920. This disposes of the table of contents and the annual subject index common to the first and second series. With the 1920 volume, therefore, the second series of the Index Medicus ends, the four quarterly numbers covering literature for 1921 being Volume I of the third series. Three numbers of the latter volume have now been issued, and from the comments and criticisms which have been made, it is evident that the views of the majority of the subscribers were correct, that the new arrangement is labor-saving and otherwise a distinct improvement upon the older one. The older arrangement of the table of contents, as a kind of hierarchy of the biological and medical sciences, had outlived its usefulness. It broke down upon the simple fact that it did not provide rubrics and compartments for a large number of subjects common to two or more of the subject-titles employed in it. It was a worn-out scheme of classification, while the newer alphabetical arrangement is not only simpler, but of infinite elasticity. This had already been fairly demonstrated in the alphabetical arrangement of the Index Catalogue of the Surgeon General's Library and in the Quarterly Cumulative Index published by the American Medical Association. The quarterly arrangement of the Third Series also presents the material in more compact form, so that a much larger array of bibliographical titles and entries can be printed in a single number than in three successive numbers of the older series for the same period.

BIOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–19.)

Progress has been made during the past year in the study of the topics previously under investigation, particularly linkage of characters in heredity and size inheritance. An intensive study is being made of the interrelations of three linked genes in rats, and of possible variations in linkage strength with age, environmental conditions, or race. In the course of this investigation more than 30,000 young rats have been produced in the last year, but the data accumulated have not as yet been studied carefully enough to warrant the formulation of conclusions. Study is also in progress of the data on size inheritance in rabbits, and this is nearly ready for publication. Linkage relations of the genes of mice are also being investigated. In rabbits a new linkage, between Angora goat and English color pattern, has been discovered. The linkage previously reported, between English pattern and dilution, with 38.5 ± 5.34 per cent cross-overs observed in the gametes of one individual, has not been confirmed in the case of a second individual, where the two genes show free assortment. It seems probable, therefore, that the first case was based on an "insufficient sample" of cases, even though the deviation from equality of cross-over and non-cross-over classes exceeded twice the probable error. Evidence for the new linkage here reported for the first time is much stronger, consisting of the progeny of three different sires, all indicating linkage.

Some new color varieties of rabbits, which are being advocated as sources of fur supply, are also being investigated genetically. One of these is the "Chinchilla," which proves to be an albino allelomorph, similar to the silver agouti variety of guinea-pig.

Four short papers have been published during the year. (See bibliography.)

Holmes, S. J., University of California, Berkeley, California. *Completion of a bibliography for use in a study of factors of evolution in man.*

The task of completing a bibliography on the "Factors of evolution in man," for which a grant was made by the Carnegie Institution of Washington, is nearly completed. During the past summer work was carried on in the John Crerar Library of Chicago, the New York Public Library, the Library of Congress, and the Surgeon General's Library at Washington, and considerable aid was received from the Eugenics Record Office at Cold Spring Harbor, Long Island. The funds remaining will be devoted to putting the references, now on cards, in type-written form, so that parts of the bibliography, at least, may be rendered available in the near future to workers in a restricted number of localities.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparations for publication of results of work on Diatomaceæ.* (For previous reports see Year Book Nos. 18–19.)

The work of diatom investigation during the past year has been to a great extent a continuation of several lines of research mentioned in my former report. The study of the marine diatoms of the Philippine Islands has been finished, so far as such unlimited fields of study can be said to be finished, and the manuscript lacks only the retouching of 35 more microphotographs of new species in order to be ready for publication.

The study of the diatom flora of Woods Hole, Massachusetts, and vicinity, has been carried forward. About a month was spent there last summer and collections were made at the same localities and at about the same period of the year as in preceding years. The ample facilities (boats, laboratory apparatus, and helpers) supplied for this purpose by the Bureau of Fisheries were made use of. Regular collections have also been made each week throughout the year, both dredgings and plankton hauls. It was also arranged to have adequate collecting done at this place during the summer. These investigations are now in their sixth year, and are nearing the time when deductions as to seasonal variation, etc., may be drawn with some safety. Undoubtedly the work should be continued; a period of ten consecutive years is probably the minimum time needed for supplying material on which to base trustworthy estimates of the normal diatom flora of this locality, or, indeed, of any other division of marine biology. The laboratory work of cleaning and making microscopic preparations of so large a number of samples is difficult; but so far all the material secured has been prepared for study.

The very important work of collecting plankton life along the Atlantic Coast, chiefly in the Gulf of Maine, is being carried forward under the direction of Dr. Henry Bigelow, of Harvard University, in collaboration with the Bureau of Fisheries. The material collected is largely diatoms and is being studied at this office. The reports consist of an enumeration of all the species represented and their relative abundance. New species, of which several have already been found, will be adequately illustrated and described. This project has an intimate bearing on the food-supply of our marine fishes and has therefore a large economic as well as a purely scientific value. Studies of this nature have been for a number of years in a far more advanced state in Europe than here, especially along the coasts of France, England, Belgium, Norway, and Sweden; so that this work, now carried on with scientific thoroughness on our side of the Atlantic is a cause for particular gratification. Arrangements are made for continuing this work during the coming year.

Work additional to that reported last year on the fossil diatoms of the Lompoc (California) bed has been done and will appear as a contribution to the extensive studies of Dr. David Starr Jordan, of Leland Stanford Junior University. This bed, one of the largest in the world, is affording material for discoveries of much scientific value.

A small but complete report has been made to the Canadian Government on the diatoms found in material collected by the Canadian Arctic Expedition. The material was submitted to this office last year, but only a cursory report was prepared. The results are to be published in the regular series of scientific monographs covering the work of that expedition.

As was the case last year, a large number of studies has been made for outside parties requesting information on subjects connected with the diatoms. The majority of these has to do with fossil diatom deposits, which are being more and more extensively utilized for various practical purposes. The number of these requests grows and will continue to grow; so that it is becoming a question as to how far this office will be justified in meeting this phase of service. Up to the present time no request of this kind has been refused. The work involved is generally small, only a few hours, rarely more than two or three days, and the service rendered is generally gratifyingly large in proportion to the labor. The fact that the information sought is so nearly unobtainable outside of this office ought also to make a willingness to accede to such requests more obligatory, and, it should be added, considerable valuable diatom material as well as some facts of scientific importance are incidentally secured in this way.

The Pacific Coast represents a territory of unusual attractiveness to diatomists because the marine flora of its extensive seaboard has been as yet very little studied, while the enormous deposits of fossil diatoms, beginning south of Los Angeles and outcropping at many places northward, are known to be unusual in the diversity of the genera and species that they contain. As above stated, some study has been given to the diatoms of the Lompoc (California) bed, but most of the Pacific deposits, while having had careful attention from geologists, have received little or no study from diatomists. Taken together, these beds represent the largest and commercially the most important diatom area known. Several invitations having come to this office to visit this territory, the suggestion has made a strong appeal. On the advice of Dr. Merriam an informal meeting of scientists whose work is more or less identified with diatom research, was held in Washington in March. The purpose of the meeting was to consider whether or not such a Pacific Coast trip would be justified; and, if so, what its scope and objectives should be. The meeting was attended by Dr. Merriam; Dr. David White of the Geological Survey; Dr. T. Wayland Vaughan, engaged in coastal biological and geological investigation; Dr. F. V. Coville, botanist of the U. S. Department of Agriculture; Dr. H. F. Moore, of the Bureau of Fisheries; and Mr. H. W. Henshaw, collaborating with the writer in diatom studies. The conclusion arrived at by this conference was that the time and expense involved in such a trip would be well invested. Accordingly plans were made and the trip was begun on June 1, 1921.

As a report of the results secured will be made after the completion of the trip, it is now necessary to merely outline the general purposes in view. It was thought best to have the trip include the entire coastline, from San Diego, California, to Vancouver, British Columbia. The places of special importance were felt to be the biological stations along the coast, where as much diatom work as possible should be done and, when practicable, assistance in collecting and research work would be offered. A study of each of the diatom beds of this area was included. Although the securing of material for the Washington office was expected, the more important object was felt to be an awakening of interest in diatom study, both on the part of those now engaged in that work and on the part of students at the various summer schools, to whom a better understanding of the large rôle the diatoms play in the economy of Nature might serve as an incentive to seriously undertake their study. In this way a more active interest in diatom research would be secured and arrangements for cooperation with this office in Washington could be made. The plan is expected to require something over three months' time. This report is written at the Scripps Biological Institute, La Jolla, California, the initial and most southern stopping-place of the journey. A little over three weeks will be spent at this point, where gratifying results are being obtained.

Two opportunities for participating in scientific research in connection with important exploring expeditions have been offered to this office and have been conditionally accepted. The first is the study of the diatoms in such material as may be secured during the projected Arctic explorations of Dr. V. Stefansson. The second is diatom study of the material obtained by the recent Australasian Antarctic Expedition. It is evident that pioneer investigations of material brought back from these remote and unknown parts of the world will be of unusual scientific importance. The samples collected by the Antarctic Expedition have been shipped from the University of London.

Morgan, T. H., A. H. Sturtevant, and C. B. Bridges, Columbia University, New York. *Study of the constitution of the germ-plasm in relation to heredity.* (For previous reports see Year Books Nos. 15–19.)

At the present time we are carrying about 240 different stocks of Drosophilas. The number of stocks is continually increasing (owing to the discovery of new mutations), although we frequently discard old ones in favor of more useful combinations. The stocks are being improved by the addition of mutants and combinations of mutants that have a special value for new lines of work. For example, new dominants, if viable, are nearly always retained on account of their value in preparing stocks for experiments; mutants that fill in gaps in the "chromosome maps" are kept for finding out what is happening in that particular part of the "chromosome"; new linkage combinations of already known mutants are made up, for they enable us to detect any changes whatsoever that may take place in a particular "chromosome."

Map of Drosophila melanogaster. Nov. 7, 1921.

Chromosome I.	
0.0	yellow*
0.0±	scute*
0.5	broad*
1.0	prune+
1.5	white*
3.0	Notch+
3.0	facet+
3.+	Abnormal
5.5	echinus*
7.3	bifid+
7.5	ruby*
12.±	roughish+
13.5	crossveinless*
16.±	club
20.0	cut*
21.0	singed+
27.5	tan*
28.0	lozenge+
33.0	vermilion*
36.0−	tiny-bristle
36.0	miniature*
37.5	dusky+
38.±	furrowed
43.0	sable+
44.5	garnet*
54.±	small-wing
54.5	rudimentary
56.5	forked*
57.0	Bar*
58.5	small-eye+
59.5	fused+
65.±	cleft
70.±	bobbed

Chromosome II.	
−2.0	telegraph
0.0	Star*
1.±	aristita+
4.±	expanded+
9.0	Truncate*
10.±	dachsous+
11.0	Gull+
14.0	Streak+
22.±	cream–b
28.±	flipper
29.0	dachs+
33.0	Ski–II*
35.±	Squat
44.±	Minute–6
46.5	black*
46.5+	jaunty
48.±	apterous
50.±	trefoil
51.±	cinnabar*
52.5	purple*
58.±	safranin
60.±	pink-wing
65.0	vestigial*
66.±	telescope
57.±	dash
70.0	Lobe*
71.±	Minute–5II
73.5	curved*
77.±	roof
85.±	Minute–2
88.±	humpy+
95.±	purpleoid
97.5	arc+
98.5	plexus*
100.±	lethal–IIa
103.0	brown*
103.±	blistered
104.5	morula+
105.0	speck*
105.5	balloon

Chromosome III.	
0.0	roughoid*
10.±	star-int.
15.±	smudge
20.±	dwarfoid
25.5	sepia*
26.0	hairy*
32.±	divergent
34.±	cream–III
38.±	vortex–III
38.5−	tilt
38.5	Dichaete*
40.±	ascute
42.0	scarlet*
42.±	varnished+
43.±	curled+
43.5	ski–III+
44.5	Deformed+
45.0	pink*
45.5	maroon+
46.0	dwarf
46.±	compressed
47.±	warped+
47.±	mahogany
48.±	raspberry+
54.0−	Two-bristle
54.0	spineless*
54.5	bithorax+
56.±	bithoraxoid
59.0	glass+
60.0	kidney
60.±	giant
61.±	spread
63.5	Delta+
65.5	Hairless*
67.5	ebony*
68.0	band
68.5	cardinal+
70.±	CIII
72.0	white–ocelli*
80.±	Minute–5III
86.5	rough*
89.0	Beaded
90.0	Pointed-wing+
95.5	claret*
96.0	Minute+
100.±	Minute–18
101.0	Minute–23

Chromosome IV.	
0.0	bent+
0.5±	shaven
1.0−	eyeless

It is important to note that whenever mutants are discarded, it is because of their poor viability, or because of too great difficulty of separation, etc., and not because they give results inconsistent with those found with other more workable mutants. Our purpose in keeping mutants is not to make a collection of them, but we keep those that are useful in attacking special problems.

Several of the stocks that were difficult to maintain, as they required selection in each generation, have been made self-perpetuating. All first-chromosome stocks that have sterile females are now maintained by two new methods. One way is to cross the male of such stock to "double-yellow" females (to be referred to later); another way is to cross the male to a mutant that is at the same time a lethal and prevents crossing-over throughout the first chromosome. The latter mutant was discovered and its application pointed out by Professor H. J. Muller.

It is interesting to note that the stocks have apparently not been reduced in vigor or in fertility, although some of the cultures have been maintained for some 200 generations. The accompanying map gives the position of about 125 loci, including corrections to November 7, 1921. To make the maps more useful in everyday work, a new graphic method is being planned for representing directly the percentage of recombination that corresponds to each particular section or region of the chromosomes.

The more accurate locations are given to the nearest half unit; the less accurate locations to the nearest unit. The more useful mutants are indicated by *; the mutants with medium usefulness are marked by +; the mutants that are unmarked are useful only in special experiments. Dominants are capitalized.

The value of these maps for the purpose for which they were constructed is continually becoming manifest. There is little excuse in misunderstanding what they stand for, but since they have been misunderstood by one or two writers, the following statement may not seem superfluous. The cross-over values on which the distances on the maps are based are known to be influenced by various conditions, such as temperature, age, and genetic factors. Nevertheless, in practice cross-over values are usually found to agree closely with the distances given on these maps. This reassures us that up to the present time no seriously complicating factors have been overlooked. When complicating factors are known to be present, and have been studied, it has always been found that the sequence of the loci is not changed. The effect of these factors is on the frequency of crossing-over and does not produce any change in the order of the genes. Therefore, while the distances are subject to some change, as we have more than once pointed out, the order of the genes remains unchanged.

As has already been reported, the only other species of *Drosophila* that has been found to cross with *melanogaster* is *D. simulans*. The hybrids are sterile, but since first-generation hybrids are obtainable it has been possible to test the allelomorphism of similar mutations. To date about 25 mutant genes have been studied in *D. simulans;* 11 of these have actually been shown to be allelomorphic to previously known mutant genes of *D. melanogaster*. Of these 7 are in the X-chromosome in both species and show the same sequence.

Another species, *D. obscura*, has been studied during the last two years by D. E. Lancefield. He has obtained upwards of 15 mutants. The chief interest in this species is that it has a different chromosome group from that of *D. melanogaster*. As C. W. Metz had shown, there are five pairs of chromosomes and the X-chromosome is nearly twice as long as the X of *melanogaster*. It is significant, therefore, to find that the chromosome map of the X is more than double the length of that of *melanogaster*. A further point of importance is that there is at least one mutant locus for every one of the chromosomes. Provided no crossing-over takes place in the male (and such has been found to be the case wherever tested), the number of "groups" corresponds to the number of the chromosomes and is one greater than that in *D. melanogaster*.

One of the types of "minutes" referred to in our last report, now called "diminished," has been found to be due to the loss of one of the IV-chromosomes. The genetic evidence indicated that such an explanation would cover the facts, and when the cells of diminished females were studied, the absence of one small round chromosome was observed. As a result of such a loss, recessive characters in the IVth chromosome appear to be dominant in the F_1 hybrid. A simple explanation as to the origin of such a haplo-IVth individual is that it arose through non-disjunction—that is, an egg had been formed in which both IV-chromosomes had been eliminated in the polar body; or at a corresponding division of sperm-cell, one cell was left with no IV-chromosome.

We have now also individuals with an additional IV-chromosome, that is, with three IV-chromosomes. Such individuals show many characteristics that are the opposite of those shown by individuals that have only one IV-chromosome. The body-color is darker than the wild type, while that of diminished is lighter than the wild type, etc. When triple-IV's are mated to eyeless (a recessive IV-chromosome character), and two F_1 triplo-IV's are mated together, the eyeless character reappears as 6 per cent of the eyeless progeny, instead of the usual 25 per cent. If such an F_1 triplo-IV is back-crossed to a normal eyeless, then among the progeny 16 per cent instead of 50 per cent are eyeless. The fact that these individuals are triplo-IV's has been demonstrated both by crosses to haplo-IV individuals and by microscopic study of the chromosomes.

Individuals with three X-chromosomes (which were formerly supposed always to die) have recently been found, showing that they do sometimes survive. They have certain structural peculiarities that enable us to identify them as a distinct type; and the way in which the sex-linked characters are distributed shows that they should possess three X-chromosomes. A study of their germ-cells reveals three X-chromosomes.

Another unusual chromosome-group has been found by L. V. Morgan in which the two X-chromosomes are attached to each other, forming a single long V-shaped chromosome. These individuals are females. When bred they show a reversal of the usual method of distribution of the sex-linked characters. Thus a "double-yellow" female bred to a wild-type male gives only yellow daughters and wild type sons. In this strain descent is from mother to daughter and from father to son.

In another strain, individuals were found that are intermediate between males and females. The distribution of mutant characters in families in which such "intersexes" are present shows that the intersexes should possess three members of the II-, III-, IV-chromosomes, but two X-chromosomes. Among the sisters of the intersexes were also found females that possessed the three members of each kind of chromosome. These were triploid individuals. Such triploids continue to produce intersexes and triploids. Since the intersexes are sterile, the stock can be continued only from triploids. The *mature* eggs of triploid females are left with either two, or only one of each chromosome, but the assortment of these chromosomes is not independent, since there are more eggs having two X's and one of each of the other chromosomes, or, vice versa, one X and two of each of the autosomes, than would be expected from random assortment. From some of the unusual chromosome combinations there are produced triplo-X individuals, triplo-IV individuals, and individuals possessing one X-chromosome, but three of each of the autosomes. All of these types have been identified. The evidence shows that individuals possessing an extra II- or an extra III-chromosome die, a result that was previously indicated by the fact that non-disjunction of these chromosomes was not met with and from a study of autosomal mosaics.

The triploid flies are larger and coarser than normals and also have large, rough eyes. Their eggs, as shown by genetic tests, contain all possible combinations of chromosomes, behaving as though non-disjunction takes place simultaneously in each set of three. Among the offspring of a triploid female (mated to a normal male) there is one class that has three II's, three III's, and three IV's, but has two X-chromosomes. This individual is an intersex, more like a male than like a female. There is another class that has three II's, three III's, but only two IV's. It also is an intersex, but more like a female.

Thus sex itself in this animal is shown to be an expression of a balance between the X-chromosomes and the autosomes. The results show that the differentials that determine sex are not confined to the sex-chromosomes alone. Some appear to be in the II- and III-chomosomes, and others in the IV-chromosome.

The possibility that some gynandromorphs arise from an egg with two nuclei has received confirmation from one conclusive case in *D. simulans*. There are some further cases that make it even more probable than formerly that the same explanation applies to some of the mosaics of *D. melanogaster*.

There is a peculiar phenomenon that has been observed from time to time in our stocks, that has seemed of sufficient interest to study in more detail. A few pure stocks that show wide variability sometimes appear to keep near that end of their variation curve that is nearest the normal fly. If this were the only observed relation it could be explained on the ground that the flies that are farthest from the normal type are more likely to die off; so that they do not appear in the mass culture. But that this is not the full explanation is shown by the fact that the absence of the more aberrant flies is not due to their elimination after hatching, as can be found by recording all the flies that hatch. Either the aberrant types die as larvæ or pupæ, or else something else has happened to such stocks. That the latter is the case is shown by breeding out the flies to wild-type stock and extracting the mutant type in question. It is then found that the original type reappears, and if such flies are inbred the stock returns to its original curve of variation. Three examples may be given. There is a tumor stock called l_7, in which all the male larvæ that carry the tumor die. The tumors can be seen as black spots in these larvæ. This stock has changed in the sense that these tumor larvæ no longer appear. But that the lethal is still present is shown by the output of a lethal-bearing female. She gives two female to one male offspring, showing that half her sons still die. The linkage relations between the lethal and other sex-linked genes present in this stock show that the missing sons are still those that would show the tumor if they developed. Evidently they now die before the tumor appears.

The stock called "bent"—a recessive IV-chromosome mutant—has always contained some flies with straight wings that are almost or entirely indistinguishable from normal flies. But the stock now consists almost entirely of normal-appearing flies. If, however, any of these are crossed to wild-type (or to any other stock, in fact), and the F_2's are inbred, extreme individuals with markedly bent wings reappear—individuals that are not found in the parent stock to-day. If these "extreme bents" are inbred, one can quickly obtain a stock, all the individuals of which are extremely bent. The result shows that the original factor for bent is still present. It has not changed, but something else has come in that has modified the bent, so that it appears under the normal form. What has happened can be studied through linkage relations, for which the *Drosophila* stock is peculiarly adapted. This work is being carried out. It appears that modifying factors have appeared in the stock of such a kind that they change the bent character back towards normal type without, of course, affecting the gene for bent itself.

Eyeless, in stock, breeds nearer the normal type eye than in stock selected from this for no eyes. The selected stock will, in time, produce a large number of flies that have no eyes at all. Here, again, the evidence shows that modifying factors are involved. A selection experiment with eyeless has been carried through 13 generations. In one direction flies with the biggest eyes have been selected in each generation, while in the other direction flies with the smallest eyes or with none at all have been selected. The two stocks are now widely different. It seems possible that a mutant allelomorph of eyeless arose, in the stock selected downwards, that produces a more eyeless condition of the eyes, and probably this effect is enhanced by the addition of modifiers. In the other direction the evidence indicates that modifying factors alone are involved.

Three new tumor stocks have been found. One is a lethal larval tumor. In the other a tumor is present in the larva and is carried over into the adult. Since the adults live and breed, this tumor is not lethal. In fact, it has not been shown in the former case that the lethal larva dies because of the presence of the tumor. On the contrary, it seems highly probable that the same agency that leads to the development of the tumor is also the one that kills the larvæ, but not through the tumor.

The question of the causes of mutation in *Drosophila* has always interested us. Many experiments have been carried out in the attempt to induce specific mutations by external agents, but since no positive results have been obtained, we have refrained from publishing much work that has been done in this direction. At present numerous attempts to call forth a larger percentage of "reversion-mutants" in the bar-eyed stock are being made. None so far has given specific results. But, nevertheless, it may be of interest to record that a series of experiments in which the eggs, larvæ, and adults were placed under very high atmospheric pressure gave no larger percentage of return-mutation than is found in the bar stock under normal conditions. At one time it seemed possible that by retarding the deposition of the eggs for 10 days or more, a higher percentage of return-mutations occurred, but on critical examination the result proved to be a non-disjunction phenomenon. In stock that can not be so closely controlled as *Drosophila* such a result might have led to a wrong conclusion concerning mutation. Finally, a method has been devised by which a related question can be tested, namely, whether when mutation takes place it involves only one member of a pair of chromosomes or both members at the same time. For the mutation problem an answer to this question is of great importance. The experiment is still under way and should in time answer the question, but first it is necessary to obtain a very large amount of data.

BOTANY.

Britton, N. L., and J. N. Rose, U. S. National Museum, Washington, D. C. *Studies of the Cactaceæ.* (For previous reports see Year Books Nos. 11–16.)

The work on the cactus project has proceeded very satisfactorily during the year. Now that the results of this investigation are being published one becomes impressed with the great amount of detail required to bring this material together.

The first volume was issued June 21, 1919, and the second September 9, 1920. The third volume is now in proof and will soon appear. The fourth volume is well advanced.

It has required more time, patience, and money to prepare for publication the results of the investigation than was anticipated, for it has been found necessary to build up large living and herbarium collections before constructive work could be done. There have been assembled in New York and Washington the largest collections of cacti that have ever been made and, inasmuch as they will form the basis of study in all future monographic work on this family, great pains have been taken to make them as complete as possible.

The field work done by the Institution has been chiefly in the cactus deserts of South America and the West Indies. It has been impossible to do any field work in Mexico since 1912, owing to the political disturbances in that country, although it is the greatest cactus region in the world.

Field work should still be done along the boundary between Texas and Mexico, where a number of species are known only from the work of the early Boundary Survey. There is also a large cactus area included in southern Brazil and Uruguay which is known only from isolated accounts and meager collections.

Fortunately, the field work of the Institution has been richly supplemented by the most generous assistance of botanists and collectors throughout North and South America. Each week brings in some rare or undescribed plant. A case in point will be of interest here. Soon after the final proof of Volume II had been sent to the printer, Dr. W. L. Abbott sent a cactus from Haiti which was identified as a very rare species, first collected by Charles Plumier about 1696, but never properly classified, and which proved to be the type of an undescribed genus. It was named *Neoabbottia* and an account of it was published in the Smithsonian Contributions to Knowledge. During the past year (September 1, 1920, to September 1, 1921) about 500 numbers of living cacti and more than 1,000 specimens have been sent in by some 60 voluntary collectors and have been grown in the cactus houses of the U. S. Department of Agriculture and of the New York Botanical Garden. A number of the duplicates have been distributed to correspondents. Considerable time has been consumed in identifying, recording, labeling, and preparing herbarium specimens and photographs from these sendings.

One phase of the cactus work has recently developed which is of great interest and may prove to be of much importance. It is well known that certain species of *Opuntia* were introduced into Australia some years ago and have since overrun thousands of acres of the best wheat lands of that country. The local states have spent large sums of money trying to eradicate this pest and two scientific commissions have visited America seeking insect enemies, but without success. A few years ago a midge was found in the cactus house of the New York Botanical Garden which threatened to destroy the entire collection of flat opuntias. It is now believed that this insect parasite was brought from the island of Curacao in 1913, and the same insect was recently found again on some plants sent from Venezuela, indicating that the native home is Venezuela and the neighboring islands. Dr. Britton has just received a letter from the entomologist employed by this second Australian Commission, stating that the fly found in the cactus house furnishes a most promising lead for the destruction of cactus plants. A series of experiments is now being arranged in southern Texas. If these parasites should destroy or even check the growth of cacti in Australia it would be of great value to civilization and in itself would justify a hundredfold the outlay which has been made on the cactus project.

CHEMISTRY.

Noyes, Arthur A., California Institute of Technology, Pasadena, California. *Researches upon (1) the properties of solutions in relation to the ionic theory, and (2) the determination of the atomic structure of crystalline substances by X-rays.* (For previous reports see Year Books Nos. 2–19.)

During the past year there have been prepared for publication the extended researches carried out during the war period with the cooperation of R. E. Wilson, R. C. Dickinson, and L. R. Westbrook on the dissociation-pressure of salt hydrates. These researches, which have now been published in the Journal of the American Chemical Society, resulted in the development of two new methods of measuring dissociation-pressure, and in determinations, more accurate than most of those previously published, of the values for some typical hydrates.

The researches on the properties of solutions in relation to the ionic theory have been continued. The state in which bismuth exists in solutions of its nitrate and perchlorate has been studied by Mr. D. F. Smith with the aid of measurements of electrical conductance and electromotive force. The results indicate that the salts mainly present in moderately dilute solutions are of the type $Bi(OH)(NO_3)_2$. The electrode-potential of metallic antimony against solutions of antimonous chloride in hydrochloric acid has also been determined by electromotive-force measurements and found to be about -0.20 volt at 25° against a solution 1 molal in antimony, in hydrogen-ion, and in chloride, this value signifying that under these conditions the antimony is less reducing than the molal hydrogen electrode by 0.20 volt.

The investigations on the determination of crystal structure by X-rays have been continued by Mr. R. M. Bozorth and Mr. R. M. Badger, with the close cooperation of Dr. R. G. Dickinson, who as National Research Fellow is pursuing researches in this field in the laboratory. The work accomplished during the past year has been mainly as follows:

An article on the crystal structure of sodium chlorate and bromate ($NaClO_3$ and $NaBrO_3$) has been prepared by Dr. Dickinson and published in the Journal of the American Chemical Society. The sodium and chlorine atoms were located with considerable certainty, and the three oxygen atoms with a fair degree of probability. Dr. Dickinson has also successfully determined the structure of potassium chlorostannate (K_2SnCl_6) and other similarly constituted compounds. These compounds, in spite of their molecular complexity, belong to the cubic crystal system; and the X-ray work has shown that the group $SnCl_6$, which in solution exists as a separate molecule (carrying two free negative electrons), maintains also in crystals its identity to the extent that the six chlorine atoms are located much closer to the tin atom than to the potassium atoms.

The arrangement of the atoms in crystals of potassium cyanide (KCN) has been determined by Mr. Bozorth. It has led to the interesting conclusion that the carbon and nitrogen atoms are located close together, so as to form a group centered in a position corresponding to that occupied by the chlorine atoms in potassium chloride. Whether there is a measurable separation of the carbon and nitrogen atoms from one another could not be fully determined.

Progress is being made in improving the method of measuring the intensities of X-ray reflections through the work of Mr. Badger, who is studying how the intensity varies with the character of the crystal surface, thus whether the surface is natural, results from cleavage, or is produced by rough grinding or fine polishing. A photo-electric apparatus to determine intensities by measuring blackness of photographic spots or lines produced by reflected rays is being developed.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and of simple compounds.* (For previous reports see Year Books, Nos. 2–19.)

(1) THE SEPARATION OF LEAD ISOTOPES.

Considerable progress was made in this investigation, with the help of Mr. Harold S. King. The fractionation of lead by the Grignard process has now progressed far enough to make it worth while to determine the atomic weights of the several fractions of which considerable amounts are at hand. This time-consuming process having been completed, the determinations will be made in the autumn. Another method also has been undertaken: fractionation by volatilization at a comparatively low temperature in an X-ray vacuum. Enough of this volatilized material is now at hand, likewise, to make a determination of the atomic weight. Diffusion methods have also been subjected to careful analysis and an apparatus, calculated to give a maximum efficiency, has been devised.

(2) THE ATOMIC WEIGHT OF RUBIDIUM.

Miss Edith H. Lanman, a graduate student of Radcliffe College, continued the study of the atomic weight of rubidium, preparing new samples from other sources by fractional crystallization of the dichloriodide. She continued further an elaborate investigation, guided by careful spectroscopic analysis, with the aim of eliminating cæsium—a difficult process because of the great similarity of the two metals. The outcome seems to have been successful and the determination of the atomic weight has already been begun.

(3) THE ATOMIC WEIGHT OF GALLIUM.

Mr. W. M. Craig prepared a new series of fractions of gallium chloride, even more carefully than before, because of the experience gained in the earlier purifications. He began the determination of the atomic weight, but the investigation was interrupted by ill health. He expects to continue it in the autumn.

(4) The Thermodynamic Behavior of Sodium Amalgams.

Mr. John Russell, 1851 Exhibition Scholar from McGill University, continued his investigation of sodium amalgams. He redetermined with greater care the heat-capacity changes on dilution and the data have been correlated and show thermodynamic consistency. Serious errors in the previous work of others have been discovered.

(5) Heat of Reaction of Slow Chemical Reactions.

Mr. Oscar C. Bridgeman has continued the study of this problem. His very complicated apparatus was perfected so that during many hours the environment of a calorimeter changing in temperature could be kept automatically to within 0.001° the same as that of the calorimeter itself. This is perhaps the most perfect adiabatic calorimeter ever constructed. Most of the year was consumed in the perfection of the apparatus, but during the last month the catalytic decomposition of methyl acetate was studied in a preliminary way. The reaction was found to be markedly endothermic, and the only further requirement for the procuring of final results on this and many other similar reactions is the preparation of chemically pure substances, which is already under way. Incidentally, while the apparatus was being perfected, the purification of methyl acetate was critically studied and several previously unsuspected causes of impurity have been detected, and (so far as can be seen) eliminated.

(6) Compressibilities of Simple Salts.

Mr. Edouard P. R. Saerens, Belgian Research Fellow, began the study of the compressibility of various simple salts, continuing the research carried out by Dr. Grinnell Jones in 1908. (See Carnegie Year Book No. 7, 1908; Journal of the American Chemical Society, vol. 31, page 158, 1909.) He undertook especially the study of the compressibility of the halides of the rarer alkali metals, beginning with cæsium chloride. The results are expected to be of especial interest in relation to the recent computations of Born concerning the nature of the distance-effect by chemical affinity, as well as in relation to atomic compressibility in general.

(7) Electrode Potentials and Junction Potentials.

With the help of Mr. Theodore Dunham jr., an investigation was conducted concerning the effect of varying hydrogen-ion concentration on the electrode potential of metals. This investigation was prompted by the peculiar behavior of gallium, discovered in the course of the previous research upon that metal and communicated in the last report. He found that the junction potentials of the several solutions gave a much larger effect than that of the acid upon the metallic electrode itself, and therefore undertook a systematic study of junction potentials, both still and flowing. The results are of considerable interest and bid fair to throw light upon the mechanism of the conduction of electricity from one part of a liquid cell to another.

(8) ADSORPTION ON GLASS SURFACES.

Dr. Emmett K. Carver, Rockefeller Research Fellow, continued his investigations of the adsorption of vapors on glass surfaces with the help of the very accurate pressure-gage mentioned in the previous report. The precautions necessary for the use of this highly sensitive instrument were further studied; and at the time of writing systematic experiments upon the adsorption of toluene on glass are being prosecuted and will be continued during the summer.

During the winter several of the investigations described in previous reports have been published in detail. References to these publications will be found in the bibliography.

Sherman, H. C., Columbia University, New York, New York. *Chemical investigation of amylases and related enzymes.* (For previous reports see Year Books Nos. 11–19.)

The experimental studies of the influence of the amino acids, glycine, alanine, phenylalanine, and tyrosine, outlined briefly in the report of last year, have been completed and prepared for publication. As pointed out in last year's report, the uniformly favorable influence of these amino acids (as well as of asparagine and aspartic acid as reported in 1919) may conceivably be due to one or more of several causes. Frequently, no doubt, the "buffer effect" of an amino acid aids the activity of an enzyme by assisting in the maintenance of a favorable hydrogen-ion concentration. In our experiments the optimum hydrogen-ion concentration for each of the three kinds of amylase chiefly used has been determined by previous studies and is regularly insured by the addition of pure salts (chloride and primary or secondary phosphate); also, frequent determinations of the concentration of hydrogen-ion in actual digestion mixtures have shown that this is not appreciably influenced by our additions of carefully neutralized amino acids, whose effects are therefore due to some more specific cause.

Since the action of a hydrolytic enzyme is frequently retarded by the accumulation of the products resulting from the hydrolysis, experiments have been performed to determine whether the amino acid favors the activity of the enzyme by combining with products which might otherwise have an inhibitory influence. Such experiments, made both with pure maltose and with a digestion mixture resulting from the action of the amylase upon soluble starch, have shown that this is not the explanation of the favorable influence exerted by the amino acids in our experiments.

On the other hand, we have found that the amino acid may have a pronounced effect in protecting the enzyme from the action of a deleterious substance, such as copper, and also in retarding the deterioration which the enzyme undergoes in the aqueous dispersion in which it acts. The experimental evidence mentioned in our last report has been extended by further work during the intervening year, which has shown that the inactivation of the enzyme by copper and its reactivation by amino acid, and the protection afforded by the amino acid against the deterioration which the enzyme undergoes in water, are processes in which time and temperature exert a marked influence. Some of these results have been prepared for publication, and further experiments, particularly with reference to the influence of temperature, are planned for the coming year. The results already obtained afford striking evidence that deterioration of the enzyme with rise in temperature is retarded by the presence of an amino acid such as glycine. Presentation of the data in quantitative terms is deferred until after the completion of further experiments.

In the experiments above described six different mono-amino acids have been employed. Another series of experiments has been carried on to test the influence of four amino acids of more complicated structure, namely arginine, histidine, tryptophane, and cystine Since these amino acids, or several of them, interfere with the determination of the reducing sugar formed by the action of the enzyme upon the starch, the method which we have commonly employed for the determination of enzymic activity of an amylase preparation based upon the measurement of its saccharogenic power, was here replaced by a method in which the amyloclastic activity of the enzyme was measured instead. Tests with two of the mono-amino acids previously tested, glycine and phenylalanine, showed that the two methods were interchangeably adapted to the demonstration of their favorable influence upon the enzymic activity of the amylase. For this series, the purified pancreatic amylase preparation was chosen, as being the form of enzyme best adapted to the purpose of these experiments. Arginine and cystine were found to resemble the mono-amino acids in their favorable influence upon the activity of this enzyme; whereas no such favorable influence was shown by histidine or tryptophane.

If the favorable influence be conceived as a direct accelerating effect exerted by the amino acid in consequence of its own chemical structure, it would seem logical to refer this effect to the presence of the α-amino group as the one common feature of all these amino acids. The failure of histidine and tryptophane to show favorable results would thus be explainable upon the ground that their heterocycles must have exerted an inhibitory influence upon the enzyme sufficient to offset the favorable influence of their α-amino group.

On the alternative hypothesis that the amino acid exerts its favorable influence by retarding the deterioration of the enzyme in the aqueous dispersion in which it acts, the differing effects of certain amino acids is readily explainable if the enzyme be regarded as essentially a protein substance or as containing protein as an essential constituent.

Deterioration of such a substance in aqueous dispersion is, then, most readily conceived as involving a hydrolytic decomposition of the protein with resulting liberation of amino acid, and such decomposition would be checked by the introduction into the solution of any one of the amino acids into which the protein material tends to be hydrolyzed. That the activity of the enzyme should be preserved it is evident that the decomposition of its protein constituent must be checked at a point earlier than that at which enzymic activity is lost. If certain amino acids split off in the course of the hydrolytic changes which result in loss of activity, while others are liberated only at later stages, then the former and not the latter might be expected to preserve the enzymic activity.

Both of these hypotheses are consistent with the facts thus far determined, and both may be correct. Both are now being subjected to further experimental investigation—that turning upon the differences in structure among the amino acids, by tests with other substances of known structure, and that resting upon the view that the enzyme is or contains a protein, subject to hydrolytic decomposition in water, by further tests of the rate of deterioration at different temperatures in the presence and absence of amino acids. That the favorable effect of glycine is more pronounced at the higher temperatures and in the tests of longer duration tends to favor the view that the enzyme is of protein nature and that the amino acid protects it. The same view is also favored by the results of a study of the influence of antiseptics upon the activity of amylases which has also been completed and prepared for publication during the past year.

The efficient work of those who have collaborated in these different investigations, whether as research assistants or volunteers, is gratefully acknowledged.

Smith, Edgar F., University of Pennsylvania, Philadelphia, Pennsylvania. *Continuation of investigations of columbium, tantalum, and tungsten, and their derivatives.* (For previous reports see Year Books Nos. 16, 17.)

Dr. Smith is making a study of the alkali tungstates, and may be engaged in this work for some time to come. They are numerous and baffling in their constitution as well as in their analysis. He has established the definiteness of several of the salts and is occupied along certain lines leading to a better understanding of their constitution. In the past, empiric formulas have been used in representing them, but there are strong evidences that formulas now being deduced are more in harmony with the constitution and behavior of these various derivatives. Much attention has been paid to what has been called the water of crystallization of the bodies. It is given in large amounts, astonishing to those looking at the chemical formulas of these bodies. Dr. Smith's study has developed that much of what has been thought to be water of crystallization is actually water of constitution. The recognition of the fact has contributed largely to the re-formulation of the many bodies being studied.

ECOLOGY.

Clements, F. E., Tucson, Arizona. *Associate in Ecology.* (For previous reports see Year Books Nos. 16–19.)

The experimental work of the year has been centered at the Alpine Laboratory from June 1 to September 15, and instrumental and aeration studies have also been carried on there through the autumn and winter. Determinations of rubber-content have been made at the Desert Laboratory during the winter and spring, and the histological investigation of laticiferous tissue has been conducted at the University of California. Statistical and garden studies in connection with experimental evolution have been made at the same institution, while the researches in the absorption of water and nutrients by roots have been carried on at the University of Nebraska. Stations for investigations in experimental vegetation and in crop ecology have maintained as heretofore at Peru, Nebraska City, and Lincoln (Nebraska), Philipsburg (Kansas), and Burlington and Colorado Springs (Colorado). During the autumn and winter taxonomic studies in connection with the monographs of *Artemisia*, *Atriplex*, and *Chrysothamnus* were pursued at the Gray Herbarium, New York Botanical Garden, and the National Herbarium.

Vegetation studies were continued in the vicinity of Tucson during the winter, and were also given major attention on three field expeditions. The first of these was through Arizona and southern California, and dealt chiefly with the contact between bunch-grass prairie and coastal sagebrush, and between the latter and the desert scrub, with dune communities, and with the distribution and amount of rubber plants, especially *Asclepias subulata*. The second traversed southern Arizona, New Mexico, northern Texas, Oklahoma, Kansas, Nebraska, and eastern Colorado. It concerned itself with the ecotone between desert scrub and desert plains, and between the latter and the short-grass plains, and gave special attention to the presence of mixed-prairie relicts in the short-grass plains, to the movement of *Poa* and *Andropogon* from the subclimax into the true prairies, and to the problems of dune and playa deposition. The third expedition was concerned primarily with succession and sedimentation in Bad Lands, the relation of grassland to the sagebrush associations, and the charting and installing of permanent quadrats. It traversed northern Colorado, southern Wyoming, Utah, Idaho, Oregon, California, and Arizona. In addition, a journey was made through the northern Rockies, the Cascades, and the Sierra Nevada for the purpose of studying variation in *Haplopappus*.

FACTOR STATIONS.

The factor stations at Pike's Peak have been changed from the series of zonal climaxes, and installed in two series, one climax, the other seral.

The former comprises the yellow pine, chaparral, and mixed-prairie communities, and the latter the successional stages on the north and south exposures of Engelmann Canyon. In these the factors measured were humidity, air and soil temperatures, water-content, light, wind, and evaporation, and the instrumental readings were supplemented by batteries of phytometers. In addition, factor stations were maintained at Peru and Lincoln (Nebraska), Phillipsburg (Kansas), and Burlington (Colorado), as well as in several communities at Lincoln. Factor instruments were also installed in the desert plain and foothill communities of the Santa Rita Range Reserve south of Tucson during the winter and spring for the purpose of studying the development of the winter annuals and grasses.

The Phytometer Method, by F. E. Clements, G. W. Goldsmith, and J. E. Weaver.

Phytometers, or standard plants, have again been employed in connection with instrumental batteries to permit a closer analysis of the efficient factors, and to furnish an integration of the habitat factors as a complex. They have been used in the yellow pine, chaparral, and plains climaxes, and in the various communities of the slope-exposure investigation in Engelmann Canyon. In concluding the preliminary study of the phytometer method, special attention has been paid to checking the methods employed, kinds of plants used, and their variability. Comparisons have been made of the effectiveness of the various methods of sealing, not only for the purpose of checking the results previously obtained, but also to improve the methods for future use. The seals employed include the ordinary wax, sheet-rubber, rubber-cement cloth, paraffin-cloth, casein-cloth, marine-glue cloth, and modeling clay. Paraffin-cloth has been found to be best adapted to field use under the conditions encountered at Pike's Peak. Sheet-rubber is excellent for short periods, but all other seals permit the entrance of water, with the exception of modeling clay.

The accurate weighing of heavy containers in the field ordinarily requires expensive apparatus that can be transported with difficulty if at all. For this reason a balance has been devised that is simple in construction and inexpensive, and that combines portability with capacity and comparatively high sensibility.

The variability in growth and transpiration per unit area has been computed for the sunflower, bean, and a representative monocotyl used as phytometers, in order to determine that the previous results are not based upon mere variations in the behavior of individual plants. With the present season the four-years development of the phytometer method is completed, and the results are now being brought together for publication.

Slope-Exposure Studies, by F. E. Clements, Dolly Lutjeharms, and T. J. Fitzpatrick.

The opposed slopes of Engelmann Canyon at the Alpine Laboratory are being investigated with reference to the factor differences of north and south exposures, and the correlation of function, growth, and vegetation with the effective factors. Two opposite stations at the same level have been selected, one in the gravel-slide community of *Aletes* on the north exposure, and the other in the pine woodland on the south exposure. A third station is located on the banks of Ruxton Creek in the bottom of the canyon. Humidity, temperature, wind, and evaporation are measured by means of recording instruments in each habitat, and light and water-content by weekly readings.

A battery of phytometers has been installed in each station. The plants employed are *Helianthus annuus, Smilacina stellata,* and *Prunus demissa.* The sunflowers were started from germinating seeds, while *Smilacina* and *Prunus* were transplanted into containers from their natural habitat. The rate of growth and transpiration was measured weekly in all three, and the wet and dry weight were determined for sunflower. Sunflowers were also placed in larger containers to serve as a check on those in the smaller ones. Finally, seedlings of *Populus tremuloides* were planted in sealed garbage-cans to permit measurements of the transpiration of trees on the different exposures.

The factor results so far obtained indicate that the two slopes are closer in air than in soil conditions, the water-content, for example, being greatest at the Ruxton, much less on the north exposure, and least on the south one. The sunflower phytometers yielded the greatest stem height and diameter at the Ruxton, but the lowest transpiration, while size was next on the south exposure and transpiration greatest, and these were more or less intermediate on the north exposure.

The Water Cycle in Plants, by F. E. Clements and J. V. G. Loftfield.

A comprehensive investigation has been begun of the water relations of plants, with especial reference to their complete behavior. Recent studies have emphasized the fact that stomatal changes and transpiration can be understood only when the sap-content of the leaf and plant as well as the water-content of the soil are known. The rate of conduction through the fibrovascular system is likewise required, as this determines the relation between sap-content and water-content. Furthermore, the existing divergence of opinion as to the echard for different species demands an extensive reinvestigation of this problem under field conditions. The rôle of soil-air and of acidity needs to be taken into account much more fully than heretofore, and finally, it has become evident that a study of water relations can not ignore photosynthesis and respiration, as these basic processes influence each other mutually.

During the summer the sap-content of the trunks and leaves and the stomatal behavior of woody plants was investigated at the Alpine Laboratory, while the absorption, conduction, transpiration, and stomatal changes of several native and cultivated herbs were followed at the Desert Laboratory. In the former, an endeavor was made to correlate the amount of water in the leaves and wood of several coniferous and deciduous trees and shrubs with transpiration and stomatal movement, and to relate these to the physical factors concerned. In the case of *Pinus ponderosa* and *Pseudotsuga mucronata* the sap-content of the trunk stood in close relation to that of the leaves, and the fluctuations shown by the dendrograph coincided with its changes. No such close relation could be established in the case of the deciduous shrubs, owing to the great variation in the sap-content of the branches.

Relation of Bud to Trunk-Growth in Conifers, by J. V. G. Loftfield.

Dendrographs were again installed in the spring on the trunks of *Picea engelmanni*, *Pseudotsuga mucronata*, and *Pinus ponderosa*, in coöperation with Dr. MacDougal. The increase in the length of buds and needles was recorded at weekly intervals and plotted in comparison with the change in the nightly maximum of the trunk. The buds of all three started to grow on the same date, June 2, but those of *Picea* completed their growth first, followed by those of *Pseudotsuga*, and later by those of *Pinus*. The trunks of the first two began to grow simultaneously with the buds, but the trunk of *Pinus* did not show growth until two weeks later. Growth was very slow during the latter part of July, and had practically ceased by the end.

An explanation of this behavior was sought in the rate at which heat penetrated the trunk. Thermometers reading to 0.1° C. were inserted 3 cm. deep in the trunks, and observed daily at 2 p. m. and at 2-hour intervals for 3-day periods at various times. It was found that the temperature of *Picea* fluctuated most nearly like that of the air, and that of *Pseudotsuga* least nearly. With respect to the rise of temperature with the afternoon sun, the spruce usually showed a decided increase in 1 hour, pine in 2, and Douglas fir in 2.5 hours, the rate corresponding approximately with the thickness of the bark.

The Significance of Transpiring Power, by R. J. Pool.

An investigation has been undertaken to determine whether there is any regular correlation between the leaf structure of plains plants and the so-called transpiring power, as indicated by the refined cobalt-paper method. Many species have been studied in the field in a wide range of habitats by this method, and abundant material has been collected for histological study in the laboratory. A considerable number of polydemics has been included, and factor readings of the various habitats are available for these as well as for other species of the different communities.

It is thought that the transpiring power, as determined by the cobalt-paper method, may furnish a means of measuring habitat differentiation. It if prove possible to determine the relative degree of xerophytism of the dominants and subdominants of each community, this method may assist materially in the classification of the habitats and stages in a given succession as well as in that of climax communities. It is evident that it can only serve as a short cut to the measurement of transpiration, and that its value must depend upon a close correlation with the latter as determined by actual field studies.

The Rôle of Soil-air in Hydrophytic Habitats, by F. E. Clements and G. W. Goldsmith.

In preparation for a comprehensive study of the significance of the air-content of the soil, a fairly complete summary of existing knowledge has been given in "Aeration and Air-content" (Carnegie Inst. Wash. Pub. 315, 1921). In resuming actual investigation, attention has been chiefly directed at the outset to swamps and bogs and to wet soils generally, as these offer the most striking effects. Ultimately, it is planned to deal with the soil-air of cultivated as well as natural soils, and to devote especial attention to the relation of soil-air to acidity and to the toxins of both bogs and agricultural soils.

The oxygen-conten and the CO_2-content, the acidity, and their effects upon the growth and transpiration of various plants, as well as the animal life, have been studied in various conditions in the cypress and coastal swamps of southern Louisiana, and in the plains swamps and alpine bogs about Pike's Peak. A compact but complete portable equipment for gas analysis has been constructed, so that all the determinations are made in the field. Winkler's method has been employed for the estimation of oxygen, and Seyler's modification of Pettenkoffer's method for determining the carbon dioxid. The acidity of samples has been determined by both colorimetric and electrometric means, but the latter has been found to yield much greater accuracy. Determinations are made either in the field or laboratory by the use of a Leeds and Northrup portable potentiometer and a Bailey hydrogen electrode. Plankton catches are made with each set of samples taken, in order to measure the complete biotic response.

In the Louisiana swamps there is usually an alkaline reserve, so that the H-ion concentration runs about pH 8, even in the poorly aerated lower layers. Nevertheless, characteristic swamp plants, as well as sunflowers, show a great reduction in the transpiration rate when grown in this water. The effect of this swamp water is marked in the case of the palmetto, *Sabal glabra*, as in the sunflower, in spite of the fact that transpiration studies indicate that it is a true xerophyte. The average rate of water-loss for 24 hours in tap-water was about 1/35 as great for the palmetto as for the sunflower, while it was more than twice as great for *Scirpus* and 3 to 5 times as great for *Typha* as for sunflower.

Photosynthetic Efficiency, by F. E. Clements and Frances Long.

While determinations of the photosynthate present in killed leaves have shown a general correspondence with light intensity, especially in the case of ecads, it has become desirable to check this method by the direct measurement of photosynthesis in the field. This not only makes possible much greater accuracy, but it also permits detailed measurement of the process throughout the day and for periods of any length. In addition, it affords the opportunity of comparing the course of photosynthesis with that of transpiration and respiration and of determining their mutual relations. As a consequence, attention has been given primarily to the problem of devising and improving a portable field apparatus. This has resolved itself into the need for compactness and for a practicable device for drawing a current of air through the container. The former has been met by the use of a celluloid chamber, which has the transparence of glass but is much lighter and less subject to injury. The latter bids fair to be best solved by the use of a fan driven by clock-work, since aspirators of various types are much less convenient in the field. Moreover, for ecological studies it is imperative to make use of the entire plant, and this demands a larger amount of CO_2 than in laboratory work with a leaf or branch, especially when full sunlight is present.

Experimental Pollination, by F. E. Clements and Frances Long.

In checking methods and results preliminary to publication, the four major lines of study have received particular attention. These are the life-history of the flower, normal pollination, experimental pollination, and competition for pollinators. The life-history from bud to fruit has again been traced in about 50 species, and a score of the representative types have been drawn in detail. Normal pollination has again been studied in the more important flowers, and the habits of the bees in particular have been checked by a study of their pollen-masses. This confirms the result that many bees work exclusively or nearly so on the preferred flower as long as it is abundant. Experimental studies with mutilated flowers, crepe flowers, painted flowers, added nectar, odor, etc., have been repeated with *Aconitum, Delphinium, Epilobium, Geranium, Rosa,* and *Rubus*. An endeavor has been made to place these upon a quantitative basis. While the results with painted flowers, for example, seem contradictory, it is becoming evident that the response of a species of bee is largely determined by the grouping of the flowers in the different types of inflorescence.

The further results of competitive studies confirm the conclusion that each species of pollinator has a preferred flower, which it visits almost exclusively during its prime. At this time the great majority of individuals can not be attracted to other flowers, no matter what their proximity, but a few will occasionally visit competition clusters.

Experimental Taxonomy, by F. E. Clements and H. M. Hall.

During the summer of 1921, attention has been given chiefly to following the development of transplants already made, though a number of alpine and plains species have been moved into the montane gardens. All previous transplants have received attention, and records have been made as to the conditions of growth, changes due to the environment, etc. Approximately 925 perennial transplants, representing 325 species and varieties, are now growing in their new habitats. A few of these were moved in 1918, but most of them have been established for only 2 years. More than 50 per cent of the plants taken from the plains to the alpine region have died. The remainder are living, but apparently the season is too short for the production of flowers and seed, or even for the development of normal foliage. Those that have made the best growth under the rigorous conditions are species of *Stipa*, *Monarda*, and *Artemisia*.

Of 100 species transferred from above timber-line (12,000 feet) to the gardens at Minnehaha (8,200 feet) but 6 have been entirely lost. This small loss is partly due to the precaution of placing every species in two or more unlike situations. The total number of plants moved from the alpine region to the montane gardens is 200, of which 48 have died. Some of those living are quite small, others are more robust than the normal alpine individuals, and 39, representing 33 species, have set flowers. It is highly desirable that a considerable quantity of each alpine species be grown at the lower altitudes to furnish material for experimental and statistical studies. With this in view a beginning has been made in transferring certain species in large quantities.

While it is yet too early to expect considerable changes in most of the transplants, some of them have already undergone extensive modification. The application of these methods to taxonomy is illustrated by the use made of results obtained from forms of *Artemisia vulgaris*. This polymorphic species is represented in the vicinity of the Colorado transplant stations by two distinct varieties commonly accepted as species. These are *ludoviciana*, in which the leaves are only sparsely pubescent above, and *gnaphalodes*, which has the foliage densely white-tomentose on both sides. These two forms were used to make a series of reciprocal transplants. After 3 years it was found that plants of *ludoviciana* had greatly increased the hairiness of the upper surface and resembled *gnaphalodes*, but that the latter had undergone little change. The taxonomic value of this lies not only in the demonstrated change of one form into another, but especially in the fact that the tomentum is shown to be more easily acquired than lost. Moreover, the results indicate that *ludoviciana* is the primitive form and *gnaphalodes* the derived one, and suggest that this is true in similar paired forms in *Artemisia.*

The Phylogenetic Method in Taxonomy, by F. E. Clements and H. M. Hall.

In emphasizing phylogeny as the basis of taxonomy, it has been found desirable to prepare monographic accounts of three complex genera, *Artemisia*, *Atriplex*, and *Chrysothamnus*, which are to be followed by others as rapidly as possible. In addition to its value in indicating methods of taxonomic research, each monograph will serve a useful purpose by presenting a logical and concise classification of the species, varieties, and minor variations comprised within the genus. In the selection of genera to be treated attention has therefore been given to economic importance as well as suitability for illustrating taxonomic principles. The genera mentioned are of the first importance as indicators of soil and climatic conditions and therefore as guides in agricultural practice. Many species of *Artemisia* and *Atriplex* possess practical value to the stock-raising industry in the West, and others are undergoing investigation as possible sources of oils, potash, etc. *Chrysothamnus* is especially important as a source of native rubber. An exact classification of the species of *Artemisia* and *Atriplex* based upon relationship is coming to be demanded by physicians and pharmacologists because of their importance as causes of hay-fever and the value of their pollen extracts in treating this malady.

The number of so-called species in each of these genera is so great and their characterization so vague in many cases that even the trained taxonomist finds difficulty in identifying them from floras and manuals, while others, such as pathologists, foresters, grazing experts, physicians, etc., either abandon the task or are led into serious errors in identification. The need of thorough revisions is still more urgent because of the almost total lack of information as to the relationships of the species as proposed by descriptive botanists. In the attempt to arrange the numerous segregated forms into a system, it has been found that they can be assembled into a comparatively small number of species. Thus, the 160 so-called species of *Artemisia* can be organized into 28 actual species, each of which is so natural and so sharply defined from its neighbors that its recognition becomes possible even for the non-taxonomist. Similarly, the 100 or more segregates of *Chrysothamnus* comprise in reality but 12 species, and the genus *Atriplex*, commonly supposed to include 120 to 200 species, yields only 48 species. These figures are for the genera as represented in North America.

It is believed that for most people a knowledge of the small number of actual species will suffice for most purposes. However, in certain lines of work the smaller units become of the first importance, especially in phylogeny and genetics. In consequence a system has been devised in which these forms are treated as natural varieties or minor variations of them and their relationships have been worked out in considerable detail. By means of a series of phyletic diagrams the degree of relationship is indicated between the various forms from the variety to the genus.

Special stress has been laid upon experimental and quantitative methods as the only adequate basis for the synthesis of minor forms into varieties and species. Consequently, much time has been given to transplant and seeding experiments, and to statistical studies both in field and herbarium. Exploration has been carried on for several years throughout the West, and herbarium studies have been pursued in most of the leading herbaria of the United States. Although the work has been considerably delayed by the endeavor to give the taxonomic status of each segregate proposed its due consideration, the monographs of *Artemisia* and *Chrysothamnus* are now completed, and that of *Atriplex* is well advanced.

Statistical Studies, by H. M. Hall.

Quantitative methods are regarded as essential if taxonomy is to advance from a descriptive to a true science. In order to aid in bringing this about much attention has been given to certain genera with the view of determining the amount of intergradation between forms and the degree of difference where intermediate stages are now wanting. The results have been used chiefly in arriving at conclusions regarding relationships. The findings are consequently of the greatest value in determining the proper taxonomic treatment of the species and varieties of the genera mentioned above. For example, the results of some 800 measurements of the style branches and appendages of *Chrysothamnus nauseosus* have demonstrated by the computation of the proper ratios that varieties *gnaphalodes* and *hololeucus* form a group entirely outside of the other 22 varieties. The characters of these two almost meet, but do not overlap those of the others. On the other hand, the remaining varieties exhibit such irregular fluctuations in these features that other characters must be employed in their classification. Similar methods, involving determinations of the number of ray-flowers, disk-flowers, bracts, etc., and the measurements of various structures with the determination of their shapes, together with the construction of graphs, have been of direct assistance in the study of *Artemisia, Atriplex, Chrysothamnus,* and other genera.

Taxonomy of Haplopappus, by H. M. Hall.

This genus of the composites has been chosen for taxonomic study because of its complexity and because it serves to illustrate the phylogenetic treatment of the segregates of a genus, especially where these are of very unequal value. *Haplopappus* is about equally well represented in North America and in western South America, comprising about 200 species, although several times this number have been proposed. Previous workers have assembled the species and minor forms in a variety of ways, and many generic segregates have been made to accommodate them. The present study is an attempt to organize the large number of forms in conformity with their evolutionary development and to present a natural and usable classification. During the year all of the material in several of the larger herbaria has been studied, and photographs secured of the more critical specimens. Field work has been prosecuted in the northern Rocky Mountains and the Great Basin, and photographs, field notes, and statistical material have been assembled for detailed study.

Rubber Plants, by H. M. Hall and Frances Long.

Studies have been continued on the rubber-content of native North American rubber plants, as also upon the life-histories of a few of the more promising species. The results of 4 years' work have been assembled and published (Carnegie Inst. Wash. Pub. 313, 1921). In this paper a report is given of the examination of 137 species of plants, of which 74 were found to contain rubber, though most of them showed but small amounts. Ten species are considered worthy of further study, and two of these, *Asclepias subulata* and *A. sullivanti*, are of especial promise. The latter carries 1.2 to 8.1 per cent of rubber in its leaves, while the former, which is a nearly leafless desert perennial, carries 2.0 to 5.2 per cent in the stems. In addition, this desert milkweed yields 43 per cent of fiber, equivalent to 28.5 per cent of bleached paper. The previous extraction of the rubber favors rather than hinders the manufacture of paper-pulp. The plants grow readily in desert soil without irrigation, and since the stems can be harvested without destroying the root, a large annual tonnage of shrub per acre may be predicted under agricultural practice. Actual commercial planting, however, must be preceded by extensive experiments in manipulation and especially in breeding, with a view to increasing the amount of rubber in the plants.

Coöperative arrangements have been entered into with plant-breeders, and with rubber and fiber experts, and the investigation is being continued along the following lines: (1) Further field exploration to discover better rubber-producing species and strains; (2) experiments in breeding and selection; (3) ecologic experiments on the effect of different habitats, pruning, and various agricultural practices;

(4) plot tests of yield under varying conditions and in different localities; (5) detailed study of the product and its uses in connection with other rubbers; (6) by-products; (7) histological and microchemical studies of the formation of rubber in plant tissues. In addition to the latex plants, these investigations will include such shrubs as *Chrysothamnus*, which yields the rubber chrysil, and guayule, a Mexican shrub now grown in Arizona and California.

Arrangements have been made by which both rubber and paper will be manufactured from these plants in sufficient quantity to permit of thorough tests as to quality, properties, and uses, as well as the yield under ordinary commercial processes. Suitable tracts for experimental planting have been offered at several places in the West, as well as stations for breeding and other experiments, and these are being utilized as rapidly as opportunity permits.

Origin and Nature of Laticiferous Tissue, by Frances Long.

In connection with the studies on rubber plants an extensive investigation has been begun of the histology and chemistry of laticiferous tissue in various groups, such as Euphorbiaceœ, Asclepiadaceœ, Cichorieœ, etc. Material has been collected in nature of most of the latex-bearing genera of the West, and particular attention has been paid to obtaining the same species in different conditions and at different times. In addition, latex plants have been grown in garden and greenhouse, partly for the purpose of obtaining milk-tissue at all stages of development and partly to permit the manipulation of water-content and light. The primary objective of the study is to determine the variations in the amount of latex and its rubber-content, and to relate these to the physical factors and the growth of the plant.

Root Development and Absorption in Crop Plants, by J. E. Weaver, F. C. Jean, and J. W. Crist.

Life-history studies of root development have been made at three or more periods in the growth of crops at Peru and Lincoln (Nebraska), Phillipsburg (Kansas), and Burlington (Colorado). In most cases the descriptions of extent and position of roots were supplemented by drawings made in the field as the roots were excavated. The experiments were repeated the following season, and the variations in root-habit recorded and correlated with the physical conditions.

The crop yield was determined in terms of grain, tubers, forage, or total dry weight. The smaller cereals were harvested from representative meter-quadrats of each species plat, the plants thoroughly air-dried and finally weighed. The yield of above-ground parts generally stood in direct relation to the water-content of the soil, being least at Burlington, intermediate at Phillipsburg, and greatest at Lincoln. Thus, the average yield of dry matter by oats, cut in the dough stage, was 180, 366, and 792 grams per square meter for the respective stations.

The root extent at each station varied but slightly from year to year. With all crops it was greatest in the mellow loess at Peru, and least in the compact silt-loam at Burlington. At Peru the smaller cereals reached depths of 6 to 8 feet, potatoes 4 to 4.5 feet, and corn 7 to 8 feet. At Burlington the hard-pan at a depth of 2.7 feet determined the limit of root extent. The lateral spread of roots in these drier soils was marked, and especially their development near the surface. Alfalfa was greatly branched in this environment, although in moister soils it normally has a pronounced tap-root free from large branches. In general, root extent at Phillipsburg was somewhat greater than at Lincoln, probably to be accounted for by exceptional seasonal rainfall.

Experiments have been carried out with barley, potatoes, corn, and certain native grasses to determine the absorption of water and nitrates at different levels throughout the period of growth. Cylindrical containers, 2 to 4 feet in diameter and 2.5 to 5 feet deep, were filled with soil and subsoil of known physical and chemical composition taken from the crop plats in such a manner that the soil had the same relative position it occupied in the field. Before filling the containers the soil from each level was thoroughly mixed, brought to the desired water-content, and certain levels impregnated with $NaNO_3$ at the rate of 400 parts per million, based on the wet weight of the soil. The soil was separated into layers a foot or less in thickness by means of a wax-seal consisting of 85 per cent paraffin and 15 per cent petrolatum, which was melted and poured upon the soil quite hot. This seal prevented the movement of water and solutes from one level to another, and was easily penetrated by the roots, as shown by their distribution in the soil-mass, as well as by the normal growth of the plants in comparison with those grown in unsealed containers and experimental plats. Barley was grown thickly in a row across the containers, and corn and potatoes in hills in the center, the stems extending through openings in the sloping wooden cover. The containers were placed in trenches in the field and the crops grown about them in such a manner as to simulate normal field conditions. The results thus far obtained show conclusively that crops absorb water at all levels to which roots penetrate, and barley, for example, in quite as large amounts from deeper as from surface soils. Similar results are indicated in regard to nitrates.

Plant Production Quadrats, by J. E. Weaver.

The study of the effect of climate upon the production of natural vegetation, begun in 1920, has been continued during the present season at the several transplant and crop stations. The usual method employed was to select 10 or more meter-quadrats in typical undisturbed areas in the climax vegetation. The height and density of the plants, the abundance of dominants and subdominants, etc., are recorded, and photographs made of representative quadrats. The vegetation is then removed by cutting it near the surface of the soil, after which it is collected, thoroughly dried, and the production determined on the basis of dry weight.

During the present season pure stands of wheat-grass (*Agropyrum glaucum*) gave yields of 400, 457, and 606 grams per square meter at the Burlington, Phillipsburg, and Lincoln stations respectively. However, the yield of buffalo-grass (*Bulbilis dactyloides*) in pure stands reached the maximum in the mixed prairie at Phillipsburg (266 gms.), while the true prairie ranked second (235 gms.), and the short-grass plains third (207 gms.). The results thus far obtained with mixtures of the dominants indicate a fairly direct correlation between the chresard and plant production. Final correlations will be possible, however, only after the studies have been continued through the climatic cycle.

The Relation of Hardpan to Root Development, by J. E. Weaver and J. W. Crist.

During the excavation of the root systems of native and crop plants in the prairie and plains associations during the past five years, so-called hardpan has been found in more than 30 localities. This characteristic layer of soil underlies much of the area with limited rainfall at depths ranging from 8 or 12 inches to 2 or 3 feet. Typical samples of hardpan have been collected at several widely separated stations for analysis, together with the soils lying above and below this layer. It is hoped that this will determine the degree to which the hardpan is due to the physical structure or to carbonates and other cementing substances. The chief effect of hardpan upon root development lies in its reduction of water penetration, though when thoroughly moist it becomes quite mellow.

Transplant Quadrats and Areas, by F. E. Clements and J. E. Weaver.

The studies in experimental vegetation, which have been carried on for the past three years, have been greatly extended during 1921. In addition to the stations already established, a new one at Peru, Nebraska, and another in the salt flats at Lincoln have been installed. Reciprocal transplants of dominant grasses have been made at several intervals at Lincoln, Tucson, Pike's Peak, and Berkeley.

In general, grass sods and seedlings establish themselves in new climates only when the rainfall and winter temperatures are not too different in the minus direction. Thus, dominants from the true prairies at Lincoln are thriving at Pike's Peak and Berkeley, while dominants from the bunch-grass prairie at La Jolla and the desert plains at Tucson establish themselves only occasionally at Lincoln, or persist for but a portion of the season. In the few cases where they have grown throughout the summer, they died during the following winter. Weather conditions for a few days following the transplanting of seedlings or for a few weeks after seeding have such a profound effect upon ecesis that it has proved desirable to repeat these operations at intervals during the spring.

The clue to ecesis is found in the study of root development, together with determinations of the light intensity in the dense vegetation of the true prairie. The highest mortality among seedlings nearly always occurs during the first three or four weeks, when the primary root is alone available for absorption and the secondary roots are in process of development. In the case of seedlings developing from seeds sown on the surface, moisture conditions are often favorable in the true prairie, but the light intensity is mostly low. The latter is usually less than 20 per cent at the surface of the soil in dense societies, and it sometimes falls as low as 1 to 2 per cent. Under such conditions the seedlings become greatly attentuated and rarely survive the summer. In mixed prairie the reduction in the light is much less, and it is of practically no consequence in the short-grass plains.

The rapidity with which the root system develops is marked, many transplants reaching the maximum extent during the first season. When they are grown in cultivated soil to eliminate the effect of competition, many sandhill dominants are able to thrive, and not a few species blossom and form seed the first season. The competition of seedlings, transplants, and sods among themselves as well as with the natural cover has been followed closely, especially in such dominants as *Agropyrum* and *Bulbilis,* which spread rapidly by rootstocks and stolons. The past season has been particularly favorable for growth at Lincoln and Phillipsburg, but so unfavorable at Burlington that even well-established tall-grass dominants have succumbed.

Climax Formations, by F. E. Clements.

All of the climax formations and associations of the West have received some study during the year. This has dealt chiefly with their structure, development, and relationship, but increasing attention is being given to their phylogeny, especially since the Pleistocene. In addition, the developmental system of classification has been further tested by means of these results, and found to be the only one that takes into account all the criteria and permits the expression of natural relationships.

The most striking discovery of the year was to the effect that the short-grass plains are not a natural community but an artificial one produced by over-grazing. It has been recognized for several years that much of the short-grass association had been derived from mixed prairie as a result of grazing, but it was not until last year that the evidence began to indicate that this was true of the entire community (Carnegie Inst. Wash. Year Book No. 19: 352). The investigation of the grassland formation in northern Arizona, northern and eastern New Mexico, and northern Texas has revealed tall-grass dominants wherever protection from grazing has existed, and leaves no question that the short-grass plains are mixed prairie greatly changed by overgrazing.

Extensive study has likewise revealed a closer relationship between the other associations of the grassland formation than was thought to exist. *Stipa comata* and *Kœleria cristata* are found to be important if not regular dominants of the original bunch-grass prairie, as well as of the mixed prairie. *Stipa pennata* belongs in the desert plains as well as in the mixed prairie, and *Bouteloua racemosa* was once as common in the southern mixed prairie as it is to-day in the subclimax prairie or the desert plains. Moreover, such typical dominants of the subclimax prairie as *Andropogon furcatus*, *A. nutans*, and *Elymus canadensis* are found in abundance with true mixed-prairie dominants on the foothills of Colorado, indicating the close relationship of these two associations. The evidence of relationship obtained from distribution is confirmed by that from phylogeny, which strongly indicates that the five grassland associations owe their present differentiation to the dry phase of a grand climatic cycle extending backward into the Pleistocene.

In the case of the scrub formations, it now appears altogether certain that the climax area of each is much smaller than that indicated by the presence of the characteristic dominants. Considerable attention has been given to determining the limits of the sagebrush and desert scrub climaxes and of the broad ecotone of savannah that separates them from the grassland. The actual sagebrush climax appears to be restricted to Utah, Nevada, and trans-Sierran California, while the focus of the desert scrub climax is in the Mohave and Colorado Deserts and adjacent Mexico. In the case of chaparral, particular attention has been paid to tracing the ecotone between it and the coastal sagebrush in California and to determining the relations of these two scrub associations to the bunch-grass prairie. The cedar-pinyon woodland and the forest formations have been studied chiefly with respect to the succession of the dominants and to the formation of natural parks and savannahs.

Natural Parks and Savannahs, by F. E. Clements and E. S. Clements.

The nature and origin of natural park and savannah have again been investigated throughout the West. The regions concerned were the Manzanita Mountains of New Mexico, the Rocky Mountains of Colorado and Wyoming, the Blue and Cascade Mountains of Oregon, the Sierra and Coast ranges of California, and the mountains of northern and central Arizona. In all of these occur natural parks of the two fundamental types, namely, those due to primary succession in lakes or swamps, and those arising out of the secondary succession in burns. Both of these exhibit the essential feature of grassland or sedgeland surrounded by trees, though they regularly show characteristic differences in the structure of the grassland, as well as of the forest mass about it. Under natural conditions all parks tend to slowly disappear, owing to the gradual invasion of trees or shrubs, but, under widespread grazing in the mountains, the seedlings are destroyed and the park will remain as long as the trees do. In the montane region natural parks usually occur in the pine or cedar-pinyon communities in the Rocky Mountains, and in the pine or Douglas fir forest on the Pacific Coast. In the subalpine region a larger number of trees is concerned, though spruce, fir, and lodgepole pine are the most important. In the former the grass center is mixed prairie in the Petran region and bunch-grass prairie in the Sierran; in the latter, it is subclimax grassland.

Natural parks are usually associated with savannah at the lower timber-line, and often also at the upper. Between these limits savannah is rare, owing to the climax nature of the forests. It is the typical expression of forest, woodland, or scrub in contact with a grassland climate, whether lowland or alpine. In appearance it closely resembles the artificial parks of cities with their grassy cover. Savannah is an expression of the cyclic nature of climatic factors, as there seems to be no doubt that it is due to the successful ecesis of woody plants during the favorable phase of a climatic cycle. Moreover, both its persistence and extension are promoted by grazing, with the result that a border of savannah is characteristic of mountain fronts that touch grassland. It is less typical of alpine timber-lines, partly owing to the relative infrequence of alpine plains, and partly to the recent advent of grazing.

Sagebrush, desert scrub, and chaparral may form natural parks as well as savannahs, but the latter are much more common. They give rise to primary parks rather infrequently, and burn parks are the rule, though these arise in chaparral usually only after repeated burning has made root-sprouting impossible. The interaction of climatic cycles and grazing has broadened the original savannah border of sagebrush and of desert scrub, until it occupies a larger area than the climax itself. The savannah character, however, is often obscured by grazing, since overgrazing often dwarfs sagebrush and mesquite so that they are over-topped by the grasses.

Comparative Studies of Forest, Chaparral, and Grassland, by R. J. Pool.

A comprehensive investigation of pine forest, chaparral, and mixed prairie is under way in the Pike's Peak region. This deals with the structure and development of each climax, but is directed especially to the interrelations of the three communities and the factors involved in the climatic control. In consequence, particular attention is being paid to the physical factors and to competition in the respective ecotones. Instrument and phytometer stations have been established in the chaparral at Colorado City, the mixed prairie at Colorado Springs, and in the pine forest on the Platte-Arkansas Divide. These have been equipped with instruments for measuring humidity, air and soil temperatures, wind, light, water-content, and evaporation, while batteries of sunflower phytometers are employed to determine differences in transpiration and growth. Changes in each community have been followed by means of permanent quadrats, while experimental quadrats are used to show the process of ecesis in detail.

Changes in Vegetation, by F. E. Clements and E. S. Clements.

Further progress has been made in tracing the profound effect of grazing on grassland and scrub and in reconstructing the grass communities as they existed a century ago. In doing this considerable evidence has been obtained of secular changes in grassland and scrub since the Pleistocene, and these furnish many suggestions as to the nature and extent of grassland during Tertiary times.

While the almost complete destruction of the bunch-grass prairie of the Pacific Coast has been caused by overgrazing, aided by fire, the final effect has differed in the two regions. In Oregon, Idaho, and Utah, the sagebrush has entered as the grass has disappeared, while in California the native perennial grasses have been replaced by exotic annual ones. This difference is due partly to fire as factor, but chiefly to the abundance of ruderal invaders available in California. This is shown by the fact that *Bromus* is now spreading rapidly through Utah and Idaho in consequence of the practice of burning the sagebrush to increase the spring forage. *Stipa comata* has been recognized as an important dominant, while *Andropogon saccharoides* forms a characteristic consociation on the driest hills in southern California. In the north, *Stipa occidentalis* seems to have been a dominant, often associated with *S. comata*, while in the south *S. coronata* is still dominant in considerable areas toward the desert edge, though it usually occurs sparsely in chaparral. *Stipa speciosa* is likewise controlling in sandy areas of Antelope Valley, and was doubtless once characteristic of such soils over a much wider area.

The mixed prairie is second only to the bunch-grass association in the degree to which it has been changed by overgrazing. The effect has been very different, however, because of the presence of the short-grasses. These have taken possession as the tall-grasses were destroyed, and have given character to the so-called short-grass plains. These were so striking in appearance and extent as to make it inevitable that they should be regarded as a distinct formation. However, a comparative study of the two soon revealed the close relationship between the short-grass plains and the mixed prairie, and the detailed investigation of the effects of grazing disclosed the widespread conversion of mixed prairie into short-grass. The survey of the mixed prairie was completed during the summer, and the universal presence of tall-grasses under the slightest protection confirmed the hypothesis that the short-grass plains are everywhere an artificial community that has arisen from mixed prairie as a result of grazing.

The desert plains resemble the bunch-grass prairie in that the dominants are largely bunch-grasses, which are replaced by scrub in consequence of grazing. The similarity in both these respects is doubtless due to a certain correspondence in water relations. The desert plains still occupy large areas in a condition but little modified, but the evidence is fairly conclusive that they once covered extensive valleys now characterized by desert scrub consisting of *Larrea*, *Prosopis*, and their associates. As with other associations, relict grass areas have been found in many places, while on certain Indian reservations, where the use has been slight, the original grassland persists over many square miles. With adequate protection good grassland has been found under a rainfall of 6 inches. Perhaps the most conclusive proof of former conditions has been furnished by seasons of exceptional rainfall, such as the summers of 1919 and 1921, when the perennial grasses reappeared in abundance in the desert valleys at Tucson and elsewhere.

The subclimax and true prairies have been modified comparatively little by grazing, perhaps chiefly because this was not a general process in a region given primarily to cultivation. When grazing was too closely restricted, as in many pastures, the tall-grasses yielded to others less affected, or were finally replaced by annual weeds. Where buffalo-grass was present, it usually became controlling, but in general pastures were sooner or later covered with a blue-grass sod. This grass has also been a successful invader of native prairies that were little disturbed, and it gives promise of completely replacing *Stipa* and *Kœleria* in regions with a rainfall of more than 27 inches. It makes headway more slowly against *Andropogon*, but may also replace it in time. While there is some question that *Poa* can invade prairie that is wholly undisturbed, this has no practical bearing, as no areas are known that are not at least mowed for hay. In these its early development and maturing and the abundance of sod-leaves gives it an advantage over the tall-grasses that mature later, and especially over the bunch-grasses, such as *Stipa* and *Kœleria*. The question of the westward movement of *Andropogon* is not yet completely settled, but this seems to be largely a matter of its reappearance after the period of intensive grazing, and perhaps also of its movement into areas left by *Stipa* and *Kœleria* as they were grazed out.

Permanent Quadrats, by F. E. Clements, E. S. Clements, and J. V. G. Loftfield.

Practically all of the permanent quadrats and transects established have been visited and recharted during the year. In addition, a considerable number of new ones has been installed, and much use has been made of the camera-set, or tristat, in determining the progress of vegetative changes. This device supplements the quadrat by recording the major changes in structure with the aid of the camera, which is placed each year in the same position by means of permanent stakes on which the tripod legs rest. A new improved form of the Hill pantograph has been devised that can be set up and alined in less than a minute, and permits charting the average quadrat in 15 minutes. By it the personal factor is almost completely eliminated, the accuracy greatly increased, and the time required diminished several times. It has made it possible to greatly extend the scope of the quadrat method, and to transform it from a time-consuming method possible only at base stations to one readily available on field-trips generally. A new type of quadrat sheet has been developed that conforms to the greater accuracy of the pantograph. This is made preferably of tracing-cloth, since its transparence not only permits copies to be made regularly, but also enables the charts for different years to be superimposed and the changes to be determined more accurately than in any other fashion. An endeavor is still being made to perfect the overhead method of quadrating by means of the camera through the use of special lenses and a fixed focus, and it is expected that this method will ultimately replace all others for quadrats of a meter or less.

A considerable extension has been made of the use of the denuded quadrat, and it is now felt that these should be installed alongside of permanent quadrats wherever a complete analysis of movement or development is required. In fact, it has become evident that experimental quadrats of various sorts are indispensable wherever causes or processes are to be analyzed. By their use it is possible to duplicate practically all habitats and seral stages, as well as to follow ecesis and competition in a manner not otherwise possible. The quadrat in all of its modifications seems more than ever the basic method in the quantitative and experimental study of vegetation, and the endeavor is now being made to refine it to the highest degree possible.

Grazing Research, by F. E. Clements and J. V. G. Loftfield.

Studies of the effect of grazing on the carrying capacity of ranges, the structure of grassland communities, the competition of grasses and shrubs, and its relation to indicator plants have again been made throughout the West. As already indicated, these have confirmed the view that grazing has profoundly modified the grasslands of arid regions, and has led to their replacement by sagebrush and desert scrub over wide areas. As a rule, overgrazing to this extent has either destroyed the carrying capacity of the range or greatly reduced it, though this has been somewhat counterbalanced by the value of the sagebrush or mesquite as browse, and especially by the extension of the buffalo-grass with its unique value as a resistant sod.

Definite grazing experiments have been conducted chiefly in Arizona. The fenced inclosures at the Grand Canyon, Williams, and Seligman in the northern part of the State have been maintained, as well as the series of exclosures on the Santa Rita Range Reserve at Tucson. In addition to the studies of Dr. Vorhies on the life-history of the kangaroo rat and the relation of its feeding and storage habits to the maintenance of the range, the effect of seasonal rainfall and temperature has received much attention. The winter of 1920-21 was nearly rainless and resulted in the almost complete suppression of the cover of winter annuals, as well as in the death of many of the bunches of perennial grasses. The summer of 1921 yielded about the normal rainfall, but this was unable to bring about the usual development of the grasses. In addition to the regular quadrats charted both winter and summer, clip quadrats were employed to determine the utilization of the various grasses and browse shrubs upon the range, and a simple practicable method was devised for estimating the amount of available forage upon it.

Experiments have been begun to determine the best methods of reseeding overgrazed ranges. Seeds of *Bouteloua rothrockii, B. eriopoda, B. racemosa,* and *Sporobolus cryptandrus* were employed, and 6 seed-plots were established for each species. The methods used were broadcast seeding, drilling, broadcasting and raking with a harrow, burning followed by broadcasting, planting, and planting with protection. A hydrothermograph was installed to make it possible to determine the relative importance of water and temperature in germination and establishment, as well as in growth. The results indicated that water was the controlling factor, but they can not be regarded as representative, owing to the exceptional dryness of the winter, and observations for a number of years will be necessary to determine the effect of each factor.

Soil Fauna of Engelmann Canyon, by G. W. Goldsmith.

The work of the previous season has been continued at representative stations in the transect across Englemann Canyon at the Alpine Laboratory. The methods employed were essentially those already described, in which soil layers of 2.5 cm. were taken successively from soil quadrats 4 dm. square. Greater accuracy in obtaining the sample for each count was obtained by using a steel frame 1 dm. square, one edge of which was sharpened. This was driven into the ground at the place desired, and the soil obtained was carefully removed and taken to the laboratory for counting. The accuracy and rapidity of this process have been increased by sifting the soil in a very thin layer over white oilcloth ruled in squares and by using a binocular magnifier to disclose the larger organisms.

A new model of the apparatus described by Holdhaus has been constructed. This consists of three 12-inch water-jacketed copper funnels with asbestos covering, each of which is connected with a central tank in which the water is kept warm by means of an alcohol blast-lamp. Actual tests of the efficiency of the apparatus have been made at various temperatures and with different organisms by placing a known number in a sample of soil and determining the percentage separated by it. In addition to the water-content, organic matter, mechanical composition, and temperature, the volume and composition of the soil atmosphere and the acidity are being determined for each habitat. It is also planned to make quantitative studies of the algæ and molds of the soil in the hope of getting at the reactions concerned.

Climatic Cycles, by F. E. Clements and A. E. Douglass.

In continuing the investigation of climatic cycles by means of the annual rings of trees, sections have been collected from the redwood at Santa Cruz, California, from pines in the Santa Rita Mountains of Arizona, and from the white pine in eastern Massachusetts. In addition, material was obtained from a group of buried pines at Flagstaff, Arizona, fragments of buried sequoia from Oroville, and a piece of wood, perhaps cypress, from the Rancho La Brea, near Los Angeles. A plotting micrometer has been constructed for the measurement of tree-rings with automatic plotting, thus rendering the process of measurement much more rapid. A general reduction has been made of 3,000-year sequoia records from 35 trees to secure the best standardized curve, and the same has been repeated in decade sums to obtain longer periods A final cutting has likewise been made for the analysis of some thirty 500-year sequoia curves for tests of topography and growth.

The preliminary analysis of the cyclic nature of rainfall in the western United States has not only shown that critical drought periods since 1835 have coincided with sun-spot maxima, but also that such periods have always occurred when maxima reach a certain degree of intensity. The rainfall of the West is now being analyzed with reference to a possible relation between wet periods and sun-spot minima, and to the relation of temperature to rainfall and to sun-spot numbers. In addition, the rainfall at certain stations and in certain regions appears to have a complementary relation to other stations or regions, and it is hoped that the examination of the records of the thousand or more stations concerned will afford some explanation of this.

Biotic Succession in Bad Lands, by F. E. Clements.

A considerable number of Bad Lands have been visited during the year. The most important of these are the Cretaceous and Eocene areas in southern Wyoming, and the Miocene of the John Day Basin in central Oregon. Other bad-land formations studied were the Barstow and the Painted Canyon of the Mohave Desert, and the Pliocene of Benson in southern Arizona. In all of these special attention was paid to present-day succession, evidences of climatic cycles, the nature and significance of sedimentation, and the utilization of bad-land areas. Some evidence has been obtained to indicate that the erosion cycles of Bad Lands correspond to climatic cycles, and that it may prove possible to correlate them with other physiographic cycles in the West that are directly or indirectly dependent upon rainfall.

It has become fairly clear that practically all Bad Lands owe their origin or their persistence to aridity, and that they are thus indicators of arid climates. It appears probable that the bad-land areas of the West originated in grassland during the arid phase of a major climatic cycle, chiefly in consequence of the effect of drought upon the grass cover. Such a cover once destroyed, increasing aridity would lead to the general production of the bad-land form, such as is typical of the desert ranges of the Southwest. A typical example of this process seems to be afforded by the Mohave Desert, which was almost certainly grassland in the fairly recent past. A study of grassland relicts in and about this desert, together with that of the grass communities that border it on the east and west, not only indicates that it was grassland a few thousand years ago, but also furnishes a somewhat detailed picture of its dominants and structure. This seems to be in entire agreement with the paleontological knowledge of its fauna, as far back as the Miocene at least. What is true of the Mohave appears to be equally if less strikingly true of other arid regions, and warrants the assumption that the Great Basin was once a vast grassland.

Researches in Sedimentation, by F. E. Clements and R. W. Chaney.

The investigation of succession in the dynamic areas of the West, such as bad lands, dunes and sandhills, lakes, swamps, and playas, has necessarily led to the detailed consideration of the processes of erosion and deposition. In the bad lands the evidences of past sedimentation were present in bewildering number alongside the present processes, and this gave promise that the one could be used in the interpretation of the other. It was evident that many of the theories as to the origin of bad-land deposits were not in harmony with the principles of plant succession, and that the latter was of peculiar value in this problem. It was felt, moreover, that the combined use of succession, climatology, and geology afforded the most promising basis not only for interpreting deposits in terms of lowland conditions, but also for sketching climatic and vegetative conditions on the uplands. As a consequence it was proposed to treat sedimentation as an essential feature of the organization of paleo-ecology and to make the Bad Lands the particular seat of investigation. Moreover, it was clearly recognized that the study of existing sedimentation must go forward at the same time, and that the best opportunity for this lay in the successional studies of bad lands, dunes, and playas already under way.

During the current year general studies of deposition have been made in various bad lands, in dunes in California and Oklahoma, and in playas from California to New Mexico. The investigation of badland strata and layers has been made chiefly in the Bridger of western Wyoming and the John Day series of central Oregon. This had to do chiefly with the thickness, order, grouping, and extent of the various beds and layers, as well as the materials, cementing substances, etc. An attempt was made to construct hypothetical topographies for certain horizons, but in the absence of areal maps for the different deposits these could be suggestive only. The general correlation of the various layers with climate and vegetation proved more feasible and afforded a number of promising leads for further study.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–19.)

The principal work of the year has been a study of the phases, relative values, and transformations of energy involved in the process of the earth's self-compression. A comparison made last year[1] between the volumes, masses, and densities of the kindred group of planetary bodies consisting of the earth, the moon, Mars, and Venus, disclosed a rising rate of increase of density with increase of mass. As all four of the bodies compared were formed within a belt covering less than 3 per cent of the radius of the planetary system, it seemed clear that this rising scale of density was a compressional effect. The next important subject to be studied was therefore the process of compression by which this notable effect was attained. There was the more reason for this because recent field studies had been disclosing new evidences that the deformations of the earth are greater than heretofore recognized. These deformations seemed to imply great stress action, and that in turn implied adequate actuating energy. The most probable source of this was the self-attraction of the earth's own substance acting compressively.

The question at once arose, what was the previous form or forms of the energy called into action to effect the compression and the deformations that attended it. It was found that the actuating forces came chiefly from potential energies of position and chemico-physical energies. The first arose from the originally scattered condition of the planet's material, and the second from such chemical and physical potentialities as could come into action in the course of the compression.

It seemed advisable to go back to the earth's beginning to see what resources of energy would be available under the different views entertained of the early evolution of the earth. A comparison was therefore made of the potential energies available at representative stages in the two main lines of descent commonly postulated. So far as potential resources of energy available for compressional and distortional action are concerned, practically all genetic hypotheses fall into the one or the other of two classes: (1) those that led to a fluid earth at the time it was first assembled, and (2) those that led to a solid earth at this and even earlier stages, for the critical differences arise mainly from the fluidal and the solid states, respectively. To be definite in the necessarily brief statement here made, it may be understood that the standard gaseo-molten earth of the old masters stands for the fluidal type and the planetesimal earth for the solid type. It will be easy to modify the deductions to fit special views, if desired.

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[1] Year Book No. 19, for the year 1920, pp. 366–383.

A working difference is to be noted at the outset: On the one hand, *thermal* or vibratory forms of energy dominated the compressional gaseo-molten descent; on the other, the properties of solidity--herein interpreted as due to revolutional motion—dominated the process during planetesimal growth; the two modes are therefore more nearly antithetical than coincident.

a. Making the usual assumptions in both cases, viz, that the earth was formed in its present position and relations in the solar system and that the established laws of dynamics were in full control, the original dispersion of the earth-forming planetesimals, conservatively estimated, was 9×10^{23} cubic miles, while that of the earth-forming gas, liberally estimated, at the time when its own gravity first came into control of it, was about 3.5×10^{18}. The ratio of the former to the latter was thus roundly 250,000 : 1.

b. For present purposes it is easiest to compare energies in terms of velocity simply, for the mass we are dealing with is the same in all cases. The earth's rotation involves a mean velocity of only a small fraction of a mile per second. It may be left out of account in the comparison, though it amounts to nearly 16×10^{28} foot-pounds. The mean revolutional velocity of the earth may be taken roundly as 18 miles per second, while the potential energy relative to the sun is about 356 miles per second. Motions and positions relative to star-clusters and the stellar galaxy, as also whatever may lie beyond, are here neglected because there is no adequate basis for estimating them. The additional energy involved in these is probably very large.

The molecular velocities of the earth in a gaseous state could not have been as high as 7 miles per second without dispersing the mass, since 6.95 miles per second is the parabolic velocity at the present earth surface. If, therefore, we take 7 miles per second as the mean velocity of the vibratory action of the molecules of the earth, it will be excessive.

The revolutional energies are therefore represented by 18^2+356^2, neglecting a large unknown value, while 7^2 is an over-generous representative of the vibratory energies. The ratio of the former to the latter is about 2600 : 1.

c. It required perhaps two or three billion years for the gathering in of the planetesimals, for they were controlled by concurrent revolutional dynamics. The gaseous nebula was of course controlled by gaseous dynamics and would have collapsed as fast as the radiation of the heat permitted, occupying not more than a few million years at most.

There was an enormous loss of energy during the concentration process in both cases. The availability of the remaining energies for making the observed compressional and diastrophic records must be considered more in detail, as follows:

1. If the earth remained fluid until all its rock-substance was condensed into a globe, all energy lost in the assembling was unavailable for making the observed deformative record, for this record could begin only after solidification began. If the earth was built up of solid accretions, these must have begun to suffer distortion as soon as one layer was laid upon another, and the distortional process must have run on through the whole history of growth. The factors of time and of rate of increase of stress, which in a very important way, condition reorganization, metamorphism, diastrophism and other forms of adjustment to stress, were thus radically different in the two cases. A gaseous assemblage is a collapsing body; an orbital organization is precisely the opposite.

2. If the earth was assembled in a fluid state, its interior suffered its main compression while still in this fluidal state, and this prevented it from leaving a full diastrophic record of its compression. If the material was added slowly, in a loose solid state, the main compression took place while in a solid state and entered into the making of the diastrophic record.

3. If the earth remained fluid and convective until fully assembled, almost ideal opportunities for chemical combination and physical adjustment, as well as chemico-physical reorganization, would have been offered before diastrophism began, except in so far as the heat itself may have restrained such action. If the matter was clastic and mixed by the conditions of infall, it would offer almost ideal conditions for recombination, readjustment, and reorganization, and this would be contemporaneous with the diastrophism.

4. If the earth was fluid until fully assembled, there should have been the best of facilities for the arrangement of the matter in concentric layers according to specific gravity. This would have been an added factor in reducing the potential energy available for diastrophism after solidification began. If the matter remained a heterogeneous mixture, so far as intrinsic heaviness was concerned, a corresponding measure of its potential energy remained available for the diastrophic record. In so far as segregation by specific gravity took place during the compressive process, it involved a distortional factor which played its part in making the diastrophic record.

5. If the earth remained fluid and convective until fully assembled, its gaseous constituents should have had favorable conditions for escape, and only the quantities required for equilibrium with the partial pressures of the constituents of the atmosphere should have been retained to take part in vulcanism. If the earth was built up by solid particles added at the surface and subject to weathering and mixture with air and water, as it was gradually buried, there should have arisen

almost ideal conditions for the evolution of volcanic gases when the mixed matter was later subjected to heat and pressure. The moon is especially instructive in this respect, for it was incompetent to hold an atmosphere of hot volcanic gases and the equilibrium quantity was zero.

6. If the earth was assembled in a fluid state, the radioactive substances should have settled toward the center because of their high specific gravities, or else, if convection prevented this, they should have been distributed subequally throughout the whole mass. But the special students of the subject have shown that if the whole earth were as rich in radioactive matter as its outer part is found to be, the heat generated would be many times greater than that now conducted to the surface and radiated away. Hence the earth should have been growing hotter throughout geological history and no shrinkage at all could be assigned to cooling. On the other hand, if the earth was built up of heterogeneous clastic matter carrying its chance portion of radioactive substances, and if these, by their heating action, led to the liquefaction of the most susceptible matter immediately inclosing them, and if such liquid matter were then forced to or toward the surface by the extrusive forces, the effect would be concentration there, in harmony with the apparent fact. So far as diastrophism is concerned, the concept of a molten earth is seriously embarrassed by this newly discovered source of heat added to the heat inherited from condensation. To the concept of a cold solid earth, the liquefying aid of radioactive substances is a welcome cooperating agency. It is obvious that in so far as heat is generated by radioactivity in the crust, the cooling of the earth is prevented and the efficiency of cooling as a deformation agency is reduced, if indeed not forestalled entirely.

When the foregoing considerations are brought together they seem to show that the resources of energy available for actuating diastrophism are scant to a serious degree in the older cosmological view of an early gaseo-molten state of the earth, while very much more ample, and seemingly quite adequate, resources of diastrophic energy are available under the accretional view. The subsequent inquiry was mainly confined to the hypothesis that thus shows adequacy.

The next step in the inquiry was a comparative study of the phases assumed by compressional energy when the body affected is solid and its resistance to compression is such as arises mainly from the properties that give it rigidity and elasticity.

COMPRESSION IN THE LIGHT OF NEW DISCOVERIES.

It is important to note at the outset the new aspect the concept of compression takes as the result of the revolution in the concept of matter. So long as atoms were supposed to be irreducible spheres, it was logical to assume that when these were pressed into contact there was an end of compression. But if atoms are revolutionary organizations, as open as a planetary system, compression of the minute flying constituents to the point of contact is out of the question, at least in the case in hand. The problem of compression takes on the form of a reduction of the orbits of revolutionary bodies, a purely dynamic question, very like those of celestial mechanics. A reduction of volume of 50 per cent or some such measure, as implied by the higher density of the earth's interior, can not be supposed to change in any radical way the revolutionary nature of the atoms that form the earth. The new view pictures the earth as an almost infinite assemblage of revolutionary systems pulled together by their own attractions. These attractions, however, are opposed by the centrifugal components of the orbital motions and the quasi-repellant effects of the interior heat. As the revolutional energy embodied in the organization of the constituents is immensely superior to the vibratory thermal energy, the crux of the problem of their cooperative function in compression lies mainly in deciphering the modes by which the orbits of the constituents are reduced, readjusted, or reorganized. As the actual field is ultra-microscopic, some general considerations from the very tangible celestial world were found helpful.

THE TWO BASAL TYPES OF KINETIC ENERGY.

There are two leading forms of kinetic energy in the great tangible world: (1) that embodied in continuous, orbital, or revolutional motion, and (2) that embodied in discontinuous, to-and-fro, or vibratory motion. The first functions in constructive work, giving rise to relatively permanent organization; the second functions in dissolution and dispersion. But this tells only the outstanding part of the story. These contrasted aspects are linked together by numerous intermediate forms of motion. Besides, though contrasted, they are often cooperative in constructional work. Agitation prepares the way for reorganization. The relative values of the energies of the two types, as embodied in the known part of the cosmos, are usually much misjudged, because the first type is singularly unobtrusive, while the second type is as singularly demonstrative. The smooth, steady gliding of a planet in its course gives little hint of its kinetic energy, while a mental effort is required to realize its potential energy. On the other hand, the radiant energies of hot bodies sharply stimulate the senses and have an impressive effect. The energy embodied in revolutional motion is, however, a high multiple of that expressed in vibratory motion, as already shown in the case of the earth.

If the analogies of the celestial world are carried into the ultra-microscopic world, where our problem lies, a similar vast preponderance of unobtrusive revolutional energy is scarcely less demonstrable. One may easily give this concrete form by selecting a familiar body, say a bowlder, and computing the shrinkage that would follow the removal of its 288° ± of absolute temperature, i. e., about 0.0057 linear, and by estimating, as well as present data permit, the energy involved in the constitution of its atoms, molecules, and crystals, or other forms of aggregation, and then comparing the two. The prodigious velocities at which the constituents of disintegrating atoms are shot forth leave little room for doubt that the subatomic energies rise to a very high order. Nor does there seem any ground for serious doubt that the motions from which these spring are revolutional. The definite periodicity of the alpha and beta discharges is cogent evidence that the motions of the protons and electrons of the parent atom are systematically organized to an extraordinary degree. On less firm, but yet very cogent, grounds it is assumed that the organization of the atoms into molecules and of the molecules into crystals or other solid aggregates is affected by the polarities and the fields of force that spring from the revolutions of the charged constituents of the atoms. While such general interpretations are certainly inadequate to cover the whole truth, there is reason to think that they are valid to the extent that the distinctive qualities of molecules and crystals are assignable to an organization of the orbital type rather than that of vibratory agitation. As an analysis of compressional energy can not well proceed without a choice between these two general types of energy, no hesitation was felt in adopting this view as a working basis.

To correlate the work of the unquestioned vibratory energies with these organizing agencies, it was assumed that when the agitation was mild it merely separated the atoms and molecules somewhat and thereby weakened their elastico-rigid holds on one another, giving the adhesions a more viscous-like nature; that when the agitation was much increased, it gave rise to fluidity, while still greater intensities of agitation led to disintegration.

These working concepts were found to form a clear-cut basis for tracing the paths of energy and for the interpreting of its functions in the work of compression.

Under this interpretation, as indeed under any other that is tenable, the revolutional or organizing energy is overwhelmingly greater than the agitative and dispersive energy, while the latter, from its nature, is fleeting and evanescent, in sharp contrast to the stability and endurance of the former.

INTERCHANGES BETWEEN THE BASAL TYPES OF ENERGY.

The next step in the inquiry was a consideration of the natural interchanges between these types of energy. Exchanges between thermal and mechanical energy are too familiar to need notice, but exchanges between vibratory and revolutional energy, or between agitative and organizing energy, need a word of explanation or of interpretation, however inadequate it must be here.

It is certain, as will appear presently, that great changes in the nature of mineral and petrological organizations have taken place, and continue to take place, in the body of the earth. Under appreciable pressure these changes take on specific phases of metamorphism. Metamorphism is here regarded as a prime factor in compression. It is perhaps an even greater factor than its mate diastrophism, because so much of compression is due to balanced stresses. Mere mechanical compression is probably largely replaced by metamorphic changes. In these metamorphic changes, energy passes from the form of heat to the forms that give organization and the reverse. The interchanges may be accompanied by increases of heat or by absorption of heat. In the main, but not exclusively, exothermic action is interpreted as the passage of revolutional or organizing energy into vibratory or disruptive energy; endothermic action, as the reverse. The whole energy of organization does not usually, if ever, appear in tangible form in the interchange, but merely the energy-difference between the states or the combinations involved.

At the surface of the earth, exothermic changes preponderate over endothermic changes, and as the exothermic changes are much the more obtrusive, their preponderance has been much exaggerated; endothermic action, even at the surface, is by no means unimportant. A reversal of this dominance, at comparatively shallow depths, has been amply shown by the researches of Van Hise and Leith and their followers.[1] Exothermic action is dominant in the zone of katamorphism; endothermic action in the zone of anamorphism. Both kinds of action, however, are present in both horizons. These actions, though antithetical, are not to be looked upon as mutually exclusive. Reversals of action probably occur at all horizons.[2]

THE CONDITIONS THAT CONTROL INTERCHANGES.

It seems to be a general principle that concentrative stress favors endothermic action; while low stress, absence of stress, or dispersive stress, favors exothermic action. This generalization is intended to have somewhat wider scope than simple mechanical pressure and its opposite, as indicated below. (It is prudent to observe, before passing on, that the factors which enter into chemico-physical changes in the earth are so complex that no simple law can be trusted to hold universally.) It seems to be a general rule that increase of stress tends toward increased *divergence* in the stress effects, i. e., the higher the stress, the more ways of relief it forces for itself. In a small sphere of gas, in open space and under mild self-compression, only the simpler types of oscillation are detectable, but as mass and self-compression increase, the internal activities become more intense, and additional forms of oscillation appear, until, if the increase continues, the whole gamut of vibratory phases from the longest dark waves to the shortest and most penetrating rays are added. It is well recognized that mechanical pressure favors endothermic action. The argument here goes somewhat beyond that and urges that the self-stress of any intense activity tends to its own divergence into varied forms to increase its modes of easement. Under this view, the high intensities of heat in the interior, as well as the high pressure, tend toward a maximum of divergences of energy there, a due portion of which, but not all, takes a reorganizing form. This is a rather distinct departure from the inherited view that all the pressure is transformed into heat and that all heat remains heat.

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[1] See the chapters on katamorphism and anamorphism in Van Hise's Treatise on Metamorphism, and Leith's and Meade's Metamorphic Geology.

[2] Compare C. K. Leith, The structural failure of the lithosphere. Vice-presidential address, Geol. Soc. of Amer., and Science, n.s., Vol. LIII (Mar. 4, 1921), pp. 205–207.

THE SIGNIFICANCE OF INTERNAL STATES.

Tidal and nutational evidences concur in indicating a higher degree of rigidity and elasticity in the interior, taken as a whole, than in the shell. Seismic evidence is quite specific in showing higher than surface rigidity and elasticity throughout perhaps seven-eighths of the volume of the earth. The remaining central part is still the subject of uncertain interpretation. Under the foregoing interpretation of the two basal types of energy, the high rigidity and elasticity of the larger part of the interior seems to imply that, in the partitions and divergencies of energy under increasing pressure and heat, the revolutional or organizing type received the higher apportionment. This is not in accord with the old interpretation, which gave heat the lion's share of all internal transformations of energy.

ULTRA-ORGANIZING EFFECTS.

The most remarkable of known exothermic effects spring from the spontaneous disintegrations of radioactive substances. No evidence that this disintegration has anything to do with relief of pressure connected with the rise of these substances from the interior is now available. So important a phenomenon can not, however, be ignored in a study that involves interior density. It is logically necessary to suppose that the present exothermic action was at some time, somewhere, and somehow, preceded by equivalent endothermic and organizing action. By interpretation, the energy now being given out was previously stored in these substances in the form of minute, inconceivably intense revolutional motions, for this seems to be implied by the regularity and the velocity of ejection of the alpha and beta particles. Perhaps the most common speculation as to the place and conditions that favored the integrating action locates it at some center of great stress of pressure and heat. The center of the earth is a place of such stress, though it may not have the requisite intensity. The alternative speculation places the integration in outer space.

Now, the problem of compression gives no special occasion to urge that any form of atomic integration took place in the heart of the earth, but it is wholesome to recognize the possibility of such action, if for no other reason than as a check on arbitrary importations of heavy material to account for internal density. The recognition of such possible integration is in keeping with the trend of cosmic philosophy under the impulse of recent discoveries and the recognized necessity for revised interpretations that shall extend the cosmic cycles. How far the organizing tendency of concentrated stress may go in the depths of the earth is an open and very stimulating question. In the light of all the considerations offered, it would be hazardous to place any narrow limit upon any constructive tendency that favors the return of runaway energy to a more stable organized form, for this is overwhelmingly the dominant form of the energy of the cosmos. But it would be equally hazardous to rest much on any specific interpretation that gets far away from observed evidences. Let us therefore turn to these evidences.

AMOUNT OF COMPRESSION IMPLIED BY THE EARTH'S MEAN DENSITY.

As just noted, the earth problem gives no occasion to push the organizing functions of pressure and heat as far as atomic integration; indeed, that might easily carry the increase of density too far to fit the evidence. If we assume that the specific gravity, 3.69, adopted by Farrington as to the mean density of meteorites, represents the density of the original material of the earth, and compare it with 5.53, adopted by Moulton as the present mean density of the earth, it would follow that the mean increase in density is only about 50 per cent. Or, if we assume that compression in the central part of the moon is offset by porosity of its outer part, and take its mean density, 3.34, as a not too low figure for the density of the original substance of the earth, the increase in its mean density would still be only a little over 65 per cent. In either case, or on any plausible assumption, some part of this must be assigned to simple mechanical compression, so that the increase of density assignable to reorganization under pressure and heat can not go very far.

DENSITY EFFECTS WITHIN THE ZONE OF OBSERVATION.

After an elaborate discussion of the most reliable data, Dr. H. S. Washington remarks in a recent paper:[1] "I am inclined to place the average density of the crust at about 2.75, at least for the uppermost shell, while that of 2.80 would probably be nearer the truth for an average of any considerable depth, say 20 or more miles." The mean depths of these two shells can scarcely be more than 8 or 10 miles apart. The rise of density in this little difference of depth, if projected to the center, as we are accustomed to project gradients of temperature, etc., would give a density nearly twice that computed from the classic law of density of Laplace. No account is here taken of mechanical compression, for the specific gravities used as the basis of the estimates were all taken under atmospheric pressure. Much less was any account taken of hypothetical quantities of metals or other specially heavy material, for both these shells are formed of common rock.

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[1] H. S. Washington, The chemistry of the earth's crust, Jour. Franklin Inst., p. 804 (Dec. 1920).

The two most abundant elements in the outer shell, oxygen and silicon, sometimes take the form of tridimite in the outermost shell but not in the plutonic rocks, where the same elements appear as quartz. This is commonly assigned to difference in the physical conditions of the two horizons, especially pressure. Now, the specific gravity of tridimite ranges from 2.28 to 2.33, while that of quartz is 2.65. This is a density rise of 15 per cent between two horizons, both of which lie in the limited zone made accessible by deformation and denudation.

The most instructive data, however, are found in the successive stages of progress in density developed in various kinds of silts as they pass into various kinds of schists, and thence into various minerals of the garnet group or allied groups of heavy minerals. The compression of the silts into shale, and even into the first forms of schist, may be neglected, since a part of the increased density is due to the mechanical elimination of porosity. But even after the early crystalline forms have been assumed, there are notable increases of density in the still higher stages of metamorphism from which the garnetic minerals arise. In the case of individual minerals these range from 36 per cent to 84 per cent, as shown by data assembled and correlated by Van Hise.[1] This rise of density is the result of the metamorphic reorganization of very common and representative kinds of material. It shows further that one order of metamorphic action may follow upon another.

So great a rise of density in the shallow zone of observation as these three specific cases imply, if extrapolated, leaves little ground for question as to the competency of metamorphic action to yield all the increase of density indicated by the mean density of the earth, when allowance is made for simple mechanical compression and for such partial segregation of the heavier material toward the center as are compatible with the planetesimal theory and even postulated by it. There seems no need to assume the presence of an amount of metal, or other intrinsically heavy material, greater than is implied by the planetary evidence already cited. Dynamic metamorphism is universally assigned to pressure and heat; these are the chief phases of energy concerned in the earth's self-compression; it is only necessary to assign them reorganizing functions in the depths of even less relative effectiveness than they show in the outer shell. The force of these considerations is much strengthened when it is considered that the rate of rise of gravitative pressure is much slower in the outer zone than in the mid-depths of the earth. An *excess* of density would be indicated, if we did not assume that the curve of density found in the outer shell, like the curve of temperature, falls off, in proportion to pressure, as the depth increases.

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[1] C. R. Van Hise, A treatise on metamorphism, Mono. U. S. G. S. XLVII, p. 299 *et seq.* (1904).

The next step in the inquiry was a consideration of the specific phases assumed by the compressional energy and the paths the energy took in passing from one phase to another.

SPECIFIC PHASES AND PATHS OF THE COMPRESSIONAL ENERGY.

For the sake of brevity, little more than conclusions can be given here.[1] It is to be understood that the earth is assumed to be a solid elastic body of heterogeneous constitution, that it was subjected to a slowly growing gravitative pressure, occupying in its rise a period of the order of two or three billion years, and that the smallness of the increments of stress in any epoch and the long time available for adjustment are important factors in the case.

The first step in the compressional process was the passage of a part of the stress into the form of strain, while another part took on the thermal form. Within elastic limits the energy of strain was stored or latent. Not a little energy has probably been thus stored all through the geologic ages. It appears from stratigraphic evidence that the strain-limit within the earth-body may become high enough under pressure to permit the accumulation of stored energy sufficient to actuate deformative "revolutions," in spite of such partial easement as may have been realized in the meantime from the milder forms of idiomolecular action about to be described.

The second step was the cooperative action of this stored energy of strain and the agitative thermal energy. The latter aided change by loosening the fixed elastico-rigid attachments of the molecules. The hold of crystals and clastic fragments upon their constituent molecules is unequal, because a portion of these lie at the angles, or on edges, or in sharp curves of the little masses, where fewer other molecules support them. The strains arising from pressure upon the interlocking crystals or fragments are also unequal for analogous reasons. It is obvious, therefore, that the particular molecules least securely held, or else those most severely strained, would yield first, easing those particular molecular strains and permitting a new adjustment of crystals or fragments, giving rise to new differences of molecular strain. The detached molecules were naturally forced to take the lines of least resistance, or else those of greatest crystalline attraction, until they reached points where new attachments were made in response to the crystalline force of some crystal so situated as to be able to grow. Such a simple detachment, transfer, and reattachment, molecule by molecule, may be regarded as the initial, and perhaps the most general, phase of metamorphic reconstruction. The process is beautifully illustrated in the granulation of snow at temperatures that inhibit[1] liquefaction. It is to be specially noted that this is the work of molecules acting *individually*. Each offers a special resistance to a special strain, and when freed follows its own path and is drawn into a special new attachment. The action is thus *idiomolecular*, and is rather sharply distinguishable from isomolecular action, such as takes place in liquid flow. Individual action of this kind makes relatively small demands on the stored energy of strain, but is correspondingly limited and slow in results, and so adequate time becomes a critical matter, but complete reconstruction may be attained in time with limited strain and limited heat.

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[1] A somewhat fuller statement will be made in the Journal of Geology, probably No. 8, 1921.

With increase of stress and consequent increase of strain, and also increase of heat, idiomolecular reorganization is hastened. Furthermore, it is likely to be concentrated along lines, planes, belts, or parallelisms of some kind. The individuality of action takes on a collective aspect without ceasing to be really individual. This may go so far as to verge toward general and simultaneous action, but close analysis seems to show that it remains idiomolecular in actual method. By such quasi-collective but really idiomolecular action, cleavage, schistosity, and other forms of structural parallelism arise. In glaciers it seems to range from the granulation of the snow to the limit of glacial motion.[2]

By further increases of stress, the strain limit may be reached and definite fracture and shear take place. The process then becomes diastrophic rather than metamorphic.

It has been very commonly held that when depths and pressures are reached that inhibit fracture, general movement of the molecules upon one another after the fashion of liquids takes place. The original idea of "rock-flow" seems to have sprung from this notion. Such a general movement of molecules upon one another, however, especially in a highly rigid body, would require a *maximum of differential stress*, for the rigid attachments of all the molecules would have to be disrupted simultaneously. Easement along a few planes, with idiomolecular adjustment between, would require much less energy, and would probably meet all the requirements of the slowly growing stresses of the interior. While the *balanced* stresses steadily grow in intensity as depth increases, general disruptions of the molecular attachments are believed to require *differential* stresses, and these are not generally supposed to reach a high order in the interior. There do not appear to be any cogent reasons why such differential strains as may there arise may not find easement by the idiomolecular method, the mass still retaining its rigidity and elasticity, as it does in the zone of observation.

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[1] C. S. Peet and E. C. Perisho, working with the writer in the winter of 1904, found by daily micrometric measurements that on the average the larger granules grew every day whether the temperature was above or below 0° C.

[2] It was from the study of the granulation of snow, the growths of glacial granules, and the development of schistosity in the glaciers of Greenland in 1894, that the importance of this individual action of molecules was realized by Chamberlin and distinguished from true flow. (Glacial studies in Greenland, Pres. Address, Geol. Soc. Amer., Bull. Geol. Soc. Amer., vol. 6, pp. 209–214, 1895.)

If there were space to go into details, many successive changes in the energy phases that enter into these idiomolecular actions, as the compression proceeds, would need to be sketched, for the specific paths of energy divide in various directions and proportions. Compression in an elastico-rigid body thus differs rather radically from compression in a liquid.

THE PART PLAYED BY TRUE FLUIDAL ACTION.

Even though the earth is held to be essentially solid, very important functions are assigned to the relatively small liquefied portions, but only what is essential to the compressive problem can be touched here, and that but briefly. The two postulated sources of liquefaction are the heat derived from compression and that from the disintegration of radioactive substances. The latter, since it can not safely be referred to compression, must be treated as an independent agency. The heat arising from radioactivity may have supplemented the heat arising from compression sufficiently to produce all the liquidity that is certainly known to have arisen. This, however, is uncertain, perhaps improbable. On the other hand, in the present state of evidence, it is doubtful whether compression, of itself, produces liquefaction in the interior. The present trend of growing evidence and of theory favors the view that increased rigidity and elasticity are the normal products of increased pressure in spite of such heat as it develops. Still, when large proportions of highly refractory material are intimately mixed with small proportions of easily liquefiable substances, it seems possible that the former may so far bear the brunt of the compressive action—taking on additional rigidity—as to permit interstitial bits of the more liquefiable—and also the more yielding—matter to measurably escape the main stress and become liquefied by the common heat developed by the compression, and so indirectly, though not directly, be liquefied by compression. At any rate, magmas of relatively small volume have come to the surface at close intervals all through the known geologic periods and continue still to come. Their relative smallness is notable and is believed to be significant; no really great outpours, without intervals between the flows, are known. Some of the batholitic intrusions seem to be more massive, but little is known of the stages of their injection.

It is important to note that the theoretical curve of temperature assignable to compression rises very slowly in the outer part of the earth. This would hold even if *all* compressive energy is reckoned as heat, which is not realized in fact. The actual gradient of temperature is notably steeper than the computed compressional temperature-curve. The actual temperature, therefore, is assigned, under the planetesimal hypothesis, to the ascent of magmas from below. There is thus reduction of heat below and gain of heat above, an equalizing thermal process. The powerful extrusive agencies of a solid globe are assumed to force practically all mobile matter outward into the cool surficial zone, whether made mobile at shallower or deeper depths. Liquefaction is thus made a persistent auxiliary of the compressive process.

The extrusion involves a suggestive chain of transformations of the compressional energy. The liquefaction in the depths involved the transformation of thermal energy into a phase which reduced rigidity and increased mobility. The mobile masses, in passing to higher horizons, exchanged heat, and perhaps exchanged substance, along their routes and increased their potential energy by their ascent. This, however, was offset by the descent of equivalent matter in the solid mass that forced the liquids up. In the cool zone the magma gave up heat which raised the regional temperature and contributed to the temperature gradients of the outer shell. By the solidification of the magmas thus squeezed outward, and by the pyro-clastic and the sedimentary derivatives from them—aided still somewhat by accessions from without—the outer shell was built up. The structure thus given it is really distinctive and requires such a revised interpretation as this to bring out its significance. It seems to be out of accord with the holomolten hypothesis. Its dominant feature is given by the necks and dikes that mark the magmatic ascents, the stocks, bulbs, and batholitic masses that mark the lodgment of magmas in the cooling zone, and the sheets and streams of overflow that mark the expansion and spread of lavas on the surface. From these, as feeding sources, the derivatives took their origins and had their special distributions. No remnants of primitive crust bearing the characteristics assignable to a holo-molten globe are in evidence. The observed temperatures have varying irregular features primarily assignable to the long series of igneous intrusions that built the outer shell, and secondarily to the earth's compression and the resulting metamorphisms and diastrophisms. The temperature gradients, like the density gradients, carry their own credentials in the form of peculiarities assignable to the special modes of their origins. The study of these is the next in order.

HISTORY OF SCIENCE.

Sarton, George, Cambridge, Massachusetts. Associate in the History of Science. (For previous reports see Year Books Nos. 18, 19.)

The general purpose of my work was set forth in my first report (Year Book No. 18, pp. 347–349). The present (third) report covers the period from September 1, 1920, to August 31, 1921.

1. *Introduction to the History and Philosophy of Science.*—I have been engaged mainly in the preparation and the writing of this introduction, the aim of which is to offer a preliminary survey of the history and philosophy of science and of every one of its branches, to provide the student with a synthetic bibliography[1] of the whole field and a master key to its problems. The fundamental purpose is to establish the history of science as an independent and organized discipline, having its own tools and methods, and placed on the same level as, say, the history of art or the history of religion. My activity is now centered upon this work because of its urgency. The writing of a full history would occupy the life-time of many scholars and until completed its normative value would remain relatively small. The outline in preparation will enable the student to survey, with comparative ease, either the total progress accomplished at any period of the past or the continuous development of each science throughout the ages; it will enable him also to undertake the study of any special subject with a sufficient knowledge of its bearings.[2]

The classification of my material was completed and the actual writing begun on January 12. The very abundance of material available both in my own and in the Widener library is such, and the unforeseen gaps and difficulties have been so many, that the work has progressed much more slowly than I had expected. However, the chapters dealing with the successive centuries from the ninth B. C. to the sixth century after Christ (inclusive) are ready for publication, subject to addition and correction. The following centuries down to the fifteenth promise to give a great deal of trouble, but from the sixteenth century on, though the complexity of science and the number of scientists increase tremendously, the treatment is on the whole easier, the moot questions being far less numerous.

2. *The publication of Isis.*—My work on the introduction has frequent small interruptions and each year two longer ones (of about a month each) because of the editing of *Isis*, the international center of information on the history of science and civilization. Such interruptions, however, do not take me entirely away from my work, but

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[1] I have explained what I mean by this in Synthetic Bibliography with special reference to the History of Science. Isis, III, 159–170, 1920.

[2] For more details see Introduction to the History and Philosophy of Science, preliminary note. Isis, IV, 23–31, 1921.

engage me in another part of it; for it would be necessary to examine and study the new books and memoirs relative to those subjects anyway. The publication of *Isis* may then be rightly considered as a byproduct of my main work. The introduction and *Isis* will complete one another.

During the past year I have edited two numbers of *Isis*, 8 and 9 (Vol. III, pp. 157–570). They contain nine papers and fifty-two reviews. The chief feature of *Isis* is, however, its critical bibliography of the history, philosophy, and organization of science and of the history of civilization; the last two bibliographies contain 855 notes covering 101 pages (on the average, 8½ notes to a page). The three first volumes of *Isis* contain about 5,620 bibliographic notes, 312 reviews, and 43 longer papers. It is very unfortunate that circumstances beyond my control oblige me to publish this journal in Belgium, since such transatlantic publication is an endless source of delay and error and a continual cause of vexation to me.

3. *The new humanism.*—I am carrying on my propaganda for this movement, that is, the reconciliation of the scientific with the humanistic spirit. The historian of science is better qualified than any one to conduct such propaganda, for his own field of research lies on the borderland between the domain of positive science and the domain of history. As soon as we realize that our knowledge of nature and of man can not be complete until we combine historical with scientific information and take the whole past into account, the history of science becomes, so to speak, the keystone of the whole structure of education.

I wrote two papers to support this movement: Science and style (*Scribner's Magazine*, vol. 69, p. 755–759, June 1921), and Herbert Spencer (*Isis* III, 375–390, 1921); and delivered a lecture before Smith College, Northampton, Massachusetts.

4. *Harvard lectures.*—I gave a course of 38 lectures on the history of science at Harvard University. I take pleasure in expressing my deep appreciation of the hospitality of this university and especially of the Widener library. What makes this library of incomparable value to me is not simply the richness of its collections, nor the fact that its books are unusually well selected and classified and as accessible to me as if they were my own, but the possibility of keeping my own *apparatus criticus* within its walls. To do in the public libraries of Oxford, London, or Paris the work I am doing now, I believe would take me at least 25 per cent more time. I must add, however, that some of the time I thus gain is miserably dissipated through the necessity of publishing most of my work, under poor conditions, across the ocean.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Research Associate in Early English Literature.* (For previous reports see Year Books Nos. 11–19.)

The first two volumes of the edition of Lydgate's "Fall of Princes," which I have been preparing under the auspices of the Institution, are still in press. These volumes contain the complete text of the poem, based on the Oxford manuscript, Bodley 263, and collated with five other manuscripts dating approximately from the middle of the fifteenth century; an introductory note, in which information is given in regard to the authorship, origin, and nature of the work; a short analysis of the meter; the prose Latin and French prefaces and dedications of Giovanni Boccaccio's "De casibus virorum illustrium" and Laurence de Premierfait's "Des cas des nobles hommes et femmes," which were used only in slight measure by Lydgate in his translation of Laurence; and, as an appendix, Lydgate's rendering from the French of "The Daunce of Machabree."

The third and concluding volume of the present edition, containing a bibliographical introduction descriptive of the manuscripts and early printed editions, explanatory notes on the text, a glossary, and an index, is already in part in an advanced state, and, provided there is no unforeseen delay, will be completed by the end of 1922.

The "Fall of Princes" is a translation in decasyllabic verse arranged in seven and eight line stanzas of the second, amplified, version (1409) of Laurence de Premierfait's French prose rendering of Boccaccio's prose Latin "De casibus virorum illustrium," a history, or narrative, told in dramatic form, of the chief events in the lives of the illustrious personages of mythology and history, "from the time of Adam to King John of France," who died in 1364. As the fate of the majority of these illustrious personages was tragic, and, as a rule, due to their vicious irresponsibility, Boccaccio wrote his book in the hope that the princes of his own time, who were equally vicious and irresponsible, might see themselves as in a mirror and learn from the unhappy example of their predecessors the virtue of wisdom and moderation. And since he believed that in consequence of the iniquity of their rulers the ordinary people were contaminated and led into evil customs, and, as a free citizen of the Florentine republic and one of the most independent minds of his era, he had no respect for hereditary privileges and titles, his book, written between the years 1355 and 1360, was filled with bitter satire. Nevertheless, owing more to the interest of its subject-matter and to the reputation for learning of its author than to its literary style—for there was no equally good compendium of universal history in existence at that time—the "De casibus" enjoyed great popularity throughout the whole of the fifteenth and sixteenth centuries; and when Laurence completed his first French version in 1400 and reissued it in an enlarged form in 1410, the book was warmly welcomed in England as well as in France by an even more influential, if not larger, public.

Lydgate began his English translation in the spring of 1430 at the request of his patron, Duke Humphrey of Gloucester, and completed if before 1439. As a distinguished and extraordinarily prolific writer of verse, it was natural for him to choose the popular rhymed decasyllabic line as his medium, and as a result of his very free rendering and the addition of "moral envoys" to each chapter (at the request of Humphrey) and the retention of Laurence's interpolations, the work grew under his hands into a huge narrative poem of over 36,000 lines, in which much of the dramatic power of Boccaccio's original was lost. In contrast to Boccaccio, Lydgate appears more often as a confidential adviser of his princes than as an accuser; he wrote as a courtier and man of the world, admonishing when he considered it necessary, but never with Boccaccio's rudeness or Laurence's servility. The spirit of his work throughout is that of a convinced monarchist patronized by royalty, a cleric fiercely intolerant of all heretical doctrines, and a skillful versifier, whose slow-minded fifteenth century readers valued wealth of circumstance and a conservative outlook on life much more than originality of thought, imaginative power, or beauty of expression. The "Fall of Princes" became one of the most popular books of its time, as the existence of some thirty manuscripts, several of them of great technical merit, attests, and was subsequently printed four times, first by Richard Pynson in 1494, and finally by John Wayland in 1558.

It is the object of the present edition to render the work accessible to students in a more correct and readable form than that of the two-columned black-letter folios of the sixteenth century; and although the literary interest of Lydgate's writings is but small in comparison with those of his "master" Chaucer, nevertheless the "Fall of Princes" is a document of considerable historical and philological importance, not only because of its relation to the earlier versions of Boccaccio and Laurence and to the later "Mirror for magistrates," but also, just as in the case of the "Troy Book," for the reason that a large number of words borrowed from the French and of uses of words both native and foreign make their first appearance in the written language on its pages.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. *Application of Cremona Groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–16, 19.)

Professor A. B. Coble has published his memoir on "Multiple binary forms with the closure property." (Amer. Jour. Math., vol. 43, pp. 1–19, Jan. 1921.)

He has begun, in the Proceedings of the National Academy of Sciences, the publication of a series of abstracts which presents results as to the nodes of the rational sextic, the symmetroid, and the modular functions of genus 4. With these there occur a variety of geometric configurations whose interrelations are of exceptional interest. Many of these are defined by multiple forms with variables drawn from different domains. The invariant theory of such forms, hitherto little used, has been a valuable auxiliary.

Some of the principal problems that hold over are the determination of the sextic or sextics of genus 4 whose modular functions define Cayley's symmetroid; of the connection between the 120 planes on three nodes of the symmetroid with the 120 tritangent planes of such a sextic; and of the automorphic Cremona group of the rational sextic and more particularly the binary group thereby induced on the parameter of the sextic.

Much of the work already accomplished is necessarily preliminary to an attack on these problems.

METEOROLOGY.

Bjerknes, V., Bergen, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics in practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–19.)

The main work of the current year has been to start a systematic publication of the results reached in the last three years by the Norwegian Weather Service (*cf.* the two last reports). Two papers are now being printed, as No. 3 and No. 4 of Vol. II of "Geofysiske Publikationer" (Cammermeyers Boghandel, Kristiania). These papers are:

J. Bjerknes and H. Solberg: Meteorological conditions for the formation of rain.

V. Bjerknes: On the dynamics of the circular vortex, with applications to the atmosphere and atmospheric vortex and wave motion.

The investigations of the first of these papers concludes with the following scheme for the classification of rain:

(1) *Cyclonic rain:* (*a*) *Warm front rain,* formed in warm air pushing upwards a retreating wedge of cold air; (*b*) *Cold front rain,* formed in warm air displaced by an advancing wedge of cold air.

(2) *Instability showers·* (*a*) Instability produced by heating from warm sea surfaces; (*b*) Instability produced by insolation over land (local showers).

(3) "*Fog-rain*" (drizzle): Slight rain formed in low layers by cooling of air in contact with relatively cold sea or land surfaces.
(4) *Orographical rain,* formed in air-currents ascending mountains.

This scheme has resulted from the daily forecasting by which the forecasters are obliged to give a plausible explanation for all rain occurring, in order to have a working hypothesis on a scientific basis, for later forecasts. The scheme accordingly contains all sorts of rain occurring in the practice of *Norwegian* forecasters, i. e., in the meteorology of northwestern Europe. The general results won by investigations of the weather in that region may probably be generalized for all other parts of the temperate and polar zones.

A subsequent paper by the same two meteorologists will treat what is now generally called the "polar front" (see previous report, Year Book, No. 19, 1920), which connects a succession of cyclones.

The second of the papers quoted above deals from a theoretical point of view with the question of this polar front and the disturbances propagating along it. Treating the entire atmosphere as a circular vortex round the earth's axis, we can first determine the equilibrium conditions of a surface of discontinuity as one which cuts the earth's surface along the polar front. Then large scale disturbances in such a surface may be discussed. These disturbances will have the character of propagating waves, but of a peculiar kind. The shallowness of the atmospheric layers compared to the wave-lengths and the dominating influence of the deviating force of the earth's rotation as soon as the time of oscillation becomes of the order of magnitude of a day, indicate that the motion of any particle will consist in a revolution in an almost *horizontal* ellipse. It is shown that the waves under these circumstances must propagate always from west to east and that in their structure they present striking analogy to propagating cyclones and anti-cyclones. This wave theory of cyclones and anticyclones also leads to important consequences for the general atmospheric circulation.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–19.)

In our report for 1919 we described the preparation of a fraction from yeast which was free from protein, fats, reducing carbohydrates, and vitamins A and C, and so rich in water-soluble vitamin B that daily doses of even so little as 16 milligrams sufficed to promote the growth of young rats at a normal rate. The possession of this product has made it possible to prepare diets of purified food substances without the introduction of such large amounts of substances of unknown nature as is the case when yeast or some other natural food product was used to supply this vitamin. Furthermore, the demonstration that small quantities of dried alfalfa suffice to furnish the daily requirement of vitamin A and latterly our observation that the same can doubtless be attained by feeding daily a few milligrams of a concentrate from cod-liver oil or from green leaves make it possible to construct dietaries in which fat *per se* is at most a minimal contamination of the ration.

By supplying the vitamins in concentrated forms we have studied the nutritive value of diets which were essentially devoid of true fats. Some years ago we reported that young rats could make satisfactory growth on diets free from fats. At that time the need of the fat-soluble vitamin A for prolonged normal growth was not recognized and as the experiments were terminated after a few weeks they have been subjected to criticism by some investigators. We have therefore repeated these experiments under conditions which subsequent experience had shown to be essential for growth during long periods. The food mixtures first used consisted of lean meat thoroughly extracted with boiling water, starch, inorganic salts, together with small quantities of alfalfa and dried brewery yeast respectively furnishing the vitamins A and B. Analyses of the rations showed that the maximum intake of fat at any time did not exceed 0.3 per cent of the food eaten. Inasmuch as all the animals starting on this "fat-free" diet with a body-weight of approximately 70 grams quadrupled their weight within the usual time, while appearing as well nourished as companion rats on diets containing liberal portions of butter fat or lard, we conclude that if true fats are essential for nutrition during growth the minimum necessary must be exceedingly small.

The foregoing experimental data are corroborated by the growth which has been observed in animals on diets in which *both* fat and carbohydrate are practically lacking. These will be considered in detail later. Unless a minute amount of fat plays as important a rôle in the metabolism of the organism as do the minute quantities of substances represented by the vitamins, it seems reasonable to assume that pure fats are dispensable constituents of the mammalian diet. We have already pointed out that the results of the foregoing investigations lead one to question seriously the contentions made, particularly during the recent war, that fats as such play some unique rôle in maintaining well-being, and further (as Maignon supposes) that they play an important rôle in the utilization of protein—a rôle which carbohydrates are powerless to fill. On the other hand, our experiments should not be construed to minimize the great value of fats as a source of energy in the usual human dietary, as well as their peculiar advantage in culinary procedures.

Carbohydrates have heretofore been regarded as indispensable components of the food intake. It has been almost universally taught that carbohydrate is essential for the proper metabolism of fats, for ketone substances may be excreted in diabetes when sugar fails to be burned up in the normal manner in the organism. On the other hand, it has been assumed that glucose can be formed from the protein molecule, or its amino-acids, under certain conditions in the metabolism, so that one could conceive carbohydrate to become available for the special needs of fat metabolism and other purposes without being specifically furnished as *preformed* carbohydrate in the diet.

By the use of rations consisting of protein (casein, edestin, or lean beef which had been thoroughly extracted with boiling water), inorganic salts, agar-agar, lard, butter fat, and 0.4 gram daily of dried brewery yeast, to furnish vitamin B, we have succeeded in making animals grow from early age to adult size on mixtures of nutrients in which the amount of digestible carbohydrate was at most exceedingly small. In some of these trials the rats have reached a weight of 360 to 440 grams in less than 160 days, thus showing a growth rarely excelled on our standard diet. In order to reduce the carbohydrate impurities in the diet still further, feeding trials have also been conducted with mixtures in which the proteins were purified until they were carbohydrate free, and vitamin B was supplied by a yeast concentrate free from demonstrable quantities of reducing carbohydrate. The other ingredients of the ration—fats and inorganic salts—were obviously also carbohydrate-free. The foods used in this series of experiments represent the highest degree of freedom from carbohydrate attainable at present; yet even on such mixtures rats already have grown at a normal rate to 270 grams. Inasmuch as it is generally assumed that diets devoid of carbohydrate readily lead to ketonuria, the urine from several of the animals on these carbohydrate-free diets was tested for acetone and diacetic acid, with negative results. Furthermore, a chemical analysis of the entire bodies of some of the animals has shown them to contain practically as much glycogen as is found in the tissues of rats fed to maturity on the standard laboratory diets in which an abundance of carbohydrate is always present. Evidently, therefore, the rat at least can manufacture the physiological quota of tissue carbohydrate from non-carbohydrate material, presumably the amino-acids.

With the dispensability of either carbohydrate or fats for the purposes of growth thus demonstrated, we fed a diet of which more than 90 per cent consisted of protein, along with 5 per cent of inorganic salts and vitamins in the form of small daily doses of dried alfalfa and brewery yeast. In these trials, still in progress, in which the vitamin-bearing substances, representing 4 to 8 per cent of the food eaten, were the only noteworthy sources of either fat or carbohydrate, some animals have grown at more than the normal rate to about 225 grams; subsequent growth, however, has been decidedly slower, so that the final outcome can not yet be forecast.

In all of the experiments on the unusual diets reported in this communication the protein content of the food mixtures was unusually high. An abundance of protein in the dietary during growth may be actually advantageous, rather than detrimental as has been suggested by certain writers. Although our experiments have not been continued long enough to show whether animals will attain full adult size and normal function on these high protein diets, they do raise a number of important problems of physiological interest and also suggest new possibilities from novel standpoints in connection with intermediary metabolism.

That animals tolerate a high concentration of carbohydrate in the diet is a matter of every-day observation. The foregoing experiments have shown a similar toleration of a high concentration of protein. Tradition, on the other hand, teaches that large quantities of fat are not so well tolerated. It must be borne in mind, however, that because food intake is limited by the energy requirement, animals eat a comparatively small quantity of foods rich in fats; consequently, when such a diet is consumed too little of the proteins, salts, and vitamins may be eaten. We have fed mixtures containing as high as 75 per cent of fat in the diet without carbohydrate, the remainder of the mixture consisting of protein and inorganic salts in such proportion as to enable the animal to secure a sufficient amount of these food factors. Enough vitamin B was supplied by daily feeding weighed quantities of yeast apart from the food mixture. Fats yielded about nine-tenths of the calories eaten by the rats thus fed. Although only a beginning has been made in this field of investigation, which presents various possibilities of importance for physiology and pathology alike, these experiments already demonstrate that large quantities of fat offer no insurmountable difficulties, even in the absence of preformed carbohydrate, which is ordinarily considered to be indispensable for the metabolism of fats.

It has been known for some time that considerable quantities of fatty acids can be utilized as food, and that during absorption they are converted into neutral fats, the glycerol thus required possibly being synthesized *de novo* in the organism, in which case the presence of carbohydrate may be essential. In view of the satisfactory growth made by animals on diets free from carbohydrates or fats, we are now undertaking investigations of the utilization of fatty acids in various proportions, with or without available glycerol or carbohydrate, in the dietaries. It is too early to foretell the results of these experiments. Owing to the need of fats during the Great War for the production of glycerol, and the corresponding accumulation of fatty acids, the possibility of the use of the latter for food purposes became a problem of national importance.

For more than a year we have been conducting an extensive series of feeding trials in which the only variable, aside from the variations in the voluntary daily food intake, has been the amount of vitamin B fed daily, as dried brewery yeast tablets, apart from the rest of the ration each day. 200 milligrams of this yeast per day sufficed at all ages for growth or maintenance, in so far as one can judge by body-weight and general appearance. With 100 milligrams per day young rats grew at a normal rate until about three-fourths the usual adult size was attained, but thereafter they ceased to gain in weight. When the daily yeast intake was reduced to 50 and to 25 milligrams respectively per day, growth was correspondingly slowed, so that with the smallest portions noted little more than maintenance has been secured after a few weeks of initial growth, although very young animals do grow for some time at a fairly good rate when receiving the minimal quantity of yeast just recorded.

Tests for the presence of vitamin B have been made with a variety of products in addition to those which we have previously investigated. Thus it has been found that dried strawberries, lettuce, and asparagus contain less vitamin B than does dried brewery yeast, inasmuch as at least 0.4 gram of these is required to produce the same effect as is readily obtained with one-half or less of this amount of dried yeast.

In view of the questions which have frequently been addressed to us regarding the desirability of long-distance shipments of dried milk, especially from the standpoint of its vitamin content, it is worthy of note that we have grown rats from 70 grams to full adult size on a diet consisting for more than a year solely of dried whole-milk powder, corn-starch, and lard.

It has been claimed that the ophthalmia which so frequently develops in animals fed on diets free from vitamin A is due primarily to infection rather than to a dietary deficiency. In this connection we have reviewed the incidence of this eye disease in 1,000 rats taken seriatim from our colony and representing essentially an entire group studied during one year under conditions in which the proximity of the animals to each other offered equal opportunity for the dissemination of contagion among all of them. We have, however, failed to observe symptoms of ophthalmia except in rats on diets deficient in the fat-soluble vitamin. This is the more striking inasmuch as a large number of the animals were suffering from other deficiencies in their foods which presumably might make them equally susceptible to contagion. The different stages of ophthalmia associated with a deficiency in vitamin A has been the subject of a highly interesting report by Dr. Wason (Jour. Amer. Med. Assn., 1921, vol. 76, 908), who has studied a large number of cases developing in our animals.

In our experience cessation of growth and ophthalmia have rarely appeared until the animals have been fed for a number of weeks on diets lacking vitamin A. Other investigators, however, have described far more prompt cessation of growth and nutritive decline upon such diets. Our results have accordingly been criticized on the ground that our diets could not have been sufficiently purified and must have contained a small, although not negligible, trace of this essential food factor. Inasmuch as we have demonstrated that fat *per se* is not essential for life, we have undertaken an entirely new series of experiments with diets from which fat and presumably vitamin A were entirely eliminated. The protein and carbohydrate were repeatedly extracted with hot alcohol and ether until the extracts left no significant residues when evaporated. Upon food mixtures containing such protein and carbohydrate, together with inorganic salts and small quantities of brewery yeast (already demonstrated to be devoid of vitamin A), the characteristic signs of deficiency have usually appeared only a few days earlier than in our previous experiments. We are forced to conclude, therefore, that other factors than the relative purity of the rations may modify the rate of onset of the deficiency symptoms in different colonies of animals. It is possible that the initial growth of our animals may be, in part at least, due to the fact that a sufficient consumption of the water-soluble vitamin was in all cases assured by feeding tablets of brewery yeast apart from the food, whereby the intake of vitamin B was wholly independent of the food intake. On several occasions we have observed in animals under conditions where both vitamins A and B have been supplied by a single source, such as alfalfa, and a slowing of growth properly attributable to a shortage of either vitamin ensued, that a renewal of growth promptly followed on feeding a small amount of yeast. This illustrates the importance of assuring an adequate intake of vitamin B whenever a possible deficiency of other vitamins is in question.

To determine the effect of the maternal diet during pregnancy upon the subsequent growth of the offspring, pregnant females were placed at various times prior to parturition upon diets practically devoid of vitamin A. When the young were born they were thus compelled to subsist upon milk secreted by a mother living upon a diet deficient in a factor which is essential for growth and which, it has been assumed, can not be manufactured *de novo* by the animal. The effect upon the offspring has been variable. In several cases the families of young grew slowly and developed ophthalmia within a few weeks. In other cases, the young appeared to be quite vigorous and grew fairly well. We can not explain these differences in vigor until further investigations are made. It is interesting to note that the character of the diet has affected the mother far less than the offspring. This is not easy to understand in view of the presumable drain upon the maternal vitamin resources during the period of lactation; nevertheless it corresponds with the frequently repeated observation that adult rats are far less sensitive to a shortage of vitamin A in the diet than are younger individuals. The uncertainty with respect to the yield of milk, or the proportion which each one of a litter actually receives, is a formidable obstacle to such investigations.

The vitamin potency of cod-liver oil and products separated therefrom have been tested anew on animals failing upon diets free from both fat and vitamin A. In several instances 14 milligrams daily have sufficed to cure ophthalmia and in some cases to promote renewal of growth. When cod-liver oil was "fractioned" by a procedure similar to that which we described several years ago in the preparation of "butter oil," the vitamin A was concentrated in the more soluble fraction; the relative potency of such preparations is now being investigated and renewed evidence of the unusual richness of cod liver oil in vitamin A is being obtained.

In agricultural practice corn or cornmeal frequently furnishes the major part of the calories of the ration. The protein deficiencies of maize are made good by the proteins of milk. The comparatively high cost of the latter makes it important to use it in the most efficient proportions. If skimmed milk is fed separately and before the cornmeal, the animal may readily eat more than enough to supplement properly the corn; if fed milk after the corn, it may eat too little. The proper way to feed these products, therefore, would be to mix them so that both may be eaten at the same time. Such a method would be particularly advantageous for those who have an irregular supply of skimmed milk, because in this way all the latter would be used under conditions of maximum efficiency. Furthermore, each individual animal would get more nearly its proper quota of the milk. We have found that mixtures of cornmeal and dried skimmed milk in which the latter furnishes one-fourth of the protein of the food permit rats to grow to full size, provided a small amount of suitable inorganic salt mixture is added as a supplement. The experiments indicate that this mixture of yellow cornmeal, skimmed-milk solids, and salts may be slightly deficient in the fat-soluble vitamin. In practice such a mixture rarely forms the sole diet of young animals, and when, as is generally the case, some green fodder is eaten, this possible deficiency would be provided for. It is possible that the deficiency in mineral matter would also be compensated in this way, but to be on the safe side it would be well to add about 1 pound each of calcium carbonate and sodium chloride per 100 pounds of cornmeal.

At the request of the officers of the American Medical Association, an exhibit of some chemical features of nutrition was prepared under our direction in cooperation with the Connecticut Agricultural Experiment Station for the Boston meeting of the association. It consisted of stuffed experimental animals and photographs and charts illustrating the results of various lines of investigation in which we have been engaged. A descriptive leaflet was distributed in connection therewith. The exhibit was awarded a certificate of merit.

In raising our stock rats we have taken great pains to exclude animals which gave evidence of disease and have regularly eliminated all the young which were under size soon after the period of weaning. The result of this has been to furnish us with an unusually vigorous stock. At the same time the average adult size of our animals, both male and female, has shown a gradual increase, so that the stock colony to-day represents a group of individuals decidedly heavier in weight than were our stock animals at a corresponding age ten years ago. One male attained a maximum weight of 615 grams at the age of 289 days. This surpasses the record for size recorded by Donaldson (The Rat, Philadelphia, 1915).

In our last report we gave an account of the proteins of the spinach leaf. This was our first attempt to study the proteins of fresh green plants. The methods devised for that investigation have since been applied to alfalfa, a forage plant of much economic importance. Further experience with these methods has led to improvements whereby it now appears to be possible to learn not only much that is new respecting the proteins of alfalfa, but also respecting its other constituents, about which little is as yet known.

While very many interesting and important observations have been made concerning the occurrence of a multitude of different substances in plants of many kinds, our present knowledge of the chemical constituents of any single green plant is fragmentary. Until a much more comprehensive knowledge of the chemical make-up of some one individual species is obtained, plant physiology, as well as plant physics, necessarily will rest on an inadequate basis. If the methods described in the following pages can be applied successfully to other green plants, it seems probable that before very long much can be learned which will fill this gap in our present knowledge of plant chemistry.

By using suitable mills and presses it has been possible to obtain relatively large quantities of the undiluted juice of the alfalfa plant and to extract the water-soluble constituents almost completely within so short a time that autolytic changes were reduced to a minimum.

After extracting with water, the chlorophyll, fats, phosphatides, etc., were extracted by cold alcohol and ether and so obtained uncontaminated with water-soluble substances which also might be soluble in these solvents.

Dilute NaOH solution was then used to extract the residue, but it was found that only a small part of the nitrogenous substances were removed, although this solvent readily dissolves nearly all known types of protein. After thus extracting with cold aqueous alkali, nearly all of the residual nitrogen was removed by boiling for a new minutes with 60 per cent alcohol containing 0.3 per cent NaOH.

After these successive extractions the residue, consisting chiefly of fibrous structures, contained only 5 per cent of the total nitrogen of the original plant. It is thus clear that, if indiffusible protein can be so completely removed as to leave so small a proportion of the nitrogen undissolved, practically all of the cells were ruptured and their contents thereby rendered available for further critical study.

Over 40 per cent of the solids of the entire plant were soluble in water, about one-fifth of which was in colloidal solution and could be precipitated by adding about 18 per cent, by weight, of alcohol. This product, which we shall call the "colloid precipitate," contained 11 to 12 per cent of nitrogen, about nine-tenths of which was almost certainly protein which comported itself towards acids, or alkalies, in such an unusual way as to suggest a type of protein hitherto unrecognized except in the spinach leaf. The balance of this precipitate consisted chiefly of calcium salts of phosphoric and organic acids, among the latter being one or more coloring substances, which in the free state were readily soluble in strong alcohol. Possibly these latter are related to the flavone pigments.

Besides this protein in colloidal solution, which is thus precipitated by quite dilute alcohol, only a little protein could be coagulated by boiling and acidifying the filtrate from which the alcohol had been previously removed by concentrating. By saturating the filtrate from the coagulum with $(NH_4)_2SO_4$ a small precipitate with properties characteristic of proteoses was obtained, but the amount of protein of this type present in the juice is at the most relatively small.

It is thus evident that the proteins of the plant juice present a wholly different picture from that given by those of any physiologically active tissue with which we are at present familiar.

After the water-soluble constituents had been removed, strong alcohol extracted only about 6 per cent of the total solids of the alfalfa plant. All of the chlorophyll was present in this extract, together with other substances, the nature of which we have not yet attempted to determine.

At room temperatures 0.3 per cent NaOH solution extracted about 5 per cent of the alfalfa solids and about 7 per cent of the nitrogen. The precipitate produced by adding a slight excess of HCl to this extract was a mixture of protein and carbohydrates. It contained nitrogen equal to only 55 per cent of protein and yielded furfurol equivalent to a content of 7.54 per cent of pentosans. Although only a very small part of the residual nitrogen was extracted by dilute aqueous NaOH solution at room temperature, nearly all of the remainder was readily dissolved by boiling for a few minutes with 60 per cent alcohol containing 0.3 per cent NaOH. This removed about 17 per cent of the alfalfa solids and 39 per cent of its nitrogen. This extract, which was dark brown in color, yielded a voluminous precipitate containing 22.8 per cent of the total alfalfa nitrogen. This doubtless consisted mostly of protein, because the dried preparation contained 14.4 per cent of nitrogen (ash-free) and gave characteristic protein reactions. Unlike the corresponding product from the alkaline aqueous extract, this precipitate was dissolved readily in a slight excess of acid or alkali. Obviously some change was caused by heating with the alkaline alcohol, otherwise this protein would have been dissolved by the aqueous alkali previously employed. Whether this protein exists in the plant cells as a conjugated protein which is thus hydrolyzed, or as an insoluble salt-like compound with some non-protein substance, possibly the pigment, which latter is altered during treatment with hot alkaline alcohol and is thereby rendered soluble, remains for further investigation to determine.

The filtrate from this precipitate contained about 60 per cent of the solids and 40 per cent of the nitrogen dissolved by the alkaline alcohol. More than half of these solids was precipitated by normal lead acetate and recovered by treating the precipitate with an excess of HCl and alcohol. Although a considerable part of the extracts containing this substance was not treated with lead acetate, almost 3 per cent of the total alfalfa solids was thus obtained. A superficial examination of this substance shows it to be much like the alcohol-soluble product extracted from the "colloid precipitate" with acid alcohol, which perhaps is related to the flavone pigments.

The intimate association of this brown pigment with the protein is striking and we are inclined to believe that future investigations will show that in the cell these are chemically combined.

The residue, after thus extracting with the several solvents, contained 30.3 per cent of the total dry solids of the alfalfa plant, but only 5.3 per cent of its nitrogen. Since indiffusible proteins can not be extracted so long as the cell walls remain intact, the small amount of nitrogen found in this residue shows that the cells had been ruptured to a greater extent than we had anticipated when this work was first undertaken.

The importance of this preliminary investigation of the alfalfa plant lies chiefly in the possibility of further studying the constituents soluble in the various solvents. Those extracted by water can be freed from those in colloidal solution by the addition of a relatively small proportion of alcohol. The non-protein, nitrogenous constituents, about the nature of which little is at present known, should now be accessible for study under exceptionally favorable conditions. It should likewise be possible to isolate definite chemical compounds from the "colloidal precipitate," especially those soluble in alcohol which appear to be related to the flavone pigments.

Since the water-soluble constituents can be extracted without removing chlorophyll and other substances directly soluble in alcohol, further studies should increase our knowledge of the substances soluble in alcohol and ether which, by the methods heretofore employed, have probably been obtained admixed with many other products also soluble in water.

The fact that hot alkaline alcohol extracts nearly all of the residual protein, together with other substances heretofore inaccessible for critical examination, should still further help to increase our current knowledge of the chemical make-up of the plant as a whole.

A new and fruitful field for future investigation thus appears to be opened which should contribute results of importance, not only for plant physiology and plant physics, but also should fill a great gap in our knowledge of the chemistry of one of the most important of the food products. We hope to continue our investigations in this new field along the lines here indicated.

In attempting to concentrate the water-soluble vitamin in fractions having a much greater potency than that of the material from which the product was obtained, or in future attempts to isolate this vitamin and to determine its chemical nature, it is important to know how various reagents affect its activity. We have accordingly tried some experiments designed to show the effect of alkali on the potency of the concentrated vitamin fraction which was described in our report for last year. We have found that when dissolved in 0.1 N NaOH for 18 hours the efficiency of this vitamin was not impaired. It was, however, seriously affected after 90 hours at this temperature. When heated to 90° with 0.1 N NaOH solution its activity was quickly destroyed.

These experiments confirm the observations of those investigators who have reported the destruction of the water-soluble vitamin B when heated with alkalies. It thus appears that in attempting to concentrate, or isolate, the water-soluble vitamin B, dilute alkaline solutions can be used without materially affecting its activity, provided a low temperature and a short time of exposure to the alkali are employed.

PALÆOGRAPHY.

Lowe, E. A., Oxford, England. *Associate in palæography.* (For previous reports see Year Books 9–16, 19.)

As a result of investigations conducted in connection with the "Bobbio Missal" and the new "Pliny Fragment," the research work of the past year has been in the field of uncial manuscripts. These researches require minute and extensive examination of all the extant material. As soon as possible it is proposed to gather the ascertainable facts and to publish them in the form of a preface to a collection of plates entitled "Dated Uncial Manuscripts." It is impossible to work upon uncial manuscripts without including in one's investigation the manuscripts in half-uncial. Uncial and half-uncial manuscripts were written between the fifth and ninth centuries and in the course of these centuries various marginal annotations were added. The types of writing used in the margins constitute the raw material out of which early minuscule scripts were formed. The notes taken on these marginalia should prove valuable for a study of the history of early minuscle writing.

All these investigations require the aid of travel and photography. The generous policy of the Institution has enabled the writer to visit the most important centers for uncial manuscripts. During the winter and spring researches were carried on in Paris, Lyons, Turin, Verona, Bologna, Florence, and Rome. The weeks spent in Paris, Lyons, Verona, and Rome were particularly profitable, as these cities are rich in our oldest manuscript material; Lyons and Verona can boast of still possessing books that were written within their walls fourteen centuries ago. In Milan it was my good fortune to decipher and identify a very ancient fragment, recently acquired, of the first book of the Æneid with a Greek translation opposite the Latin. The fragment is unique. The writer's thanks are due to the officers of all the libraries visited for various courtesies and permission to get photographs. During the past year short articles were published in the "Berliner Philologische Wochenschrift," "The Classical Quarterly," and "The English Historical Review." "A Sixth Century Fragment of the Letters of Pliny the Younger" is now in press.

PALÆONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and palæogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8–19.)

Work under this grant was begun with the idea of establishing by a concrete illustration the necessity for recognition by all workers in palæobiology that an enumeration of the morphological characters of an organism and any proposals for taxonomic or phyletic arrangements, based on morphological characters alone, are inadequate to serve the purposes of palæontological inquiries in the present stage of scientific knowledge.

Palæogeography has been regarded for too long and by too many men as a record of the limits of bodies of land and water during definite periods of geological time. Maps based upon the recorded occurrence of strata, correlated by methods which have been under discussion for a long period, and the accuracy of which is open to serious question, are of greater or less accuracy as determined by the amount and clarity of the data and the wisdom of the producer. They have been an invaluable aid or have resulted in material advance of knowledge because of the criticism applied to them.

The delimitation of areas of aggradation or degradation is, however, but a small element in the answer to any palæogeographic problem. Such limits are the result of diastrophism of greater or less degree and serve their main purpose in helping to isolate definite periods of development in the earth's history.

Palæogeography has a far wider field and can only be defined in the terms of neogeography. However different the concepts of the content of this subject may be, and however widely the different and specialized branches of the subject may diverge from each other in content and method of approach, the central idea remains unchanged. Diversely expressed by many writers, the fundamental idea is that "geography treats of the response of the living organism to its environment."

The application of this principal idea to palæogeography introduces elements of the first order which immensely complicate the subject. The neogeographer may observe the organism in its actual environment; the palæogeographer must first restore the environment and the organisms as perfectly as may be, by all the resources of several branches of science, before the question of responses within the complex can be taken up.

A tentative plan of attack and method of procedure has been outlined in Chapter I of Publication 283 of the Carnegie Institution of Washington, and a concrete illustration of the use of the method given in the remaining chapters of the same publication. In this study the earlier series of publications by the same author on the morphology of the Permo-carboniferous vertebrates of North America was taken as establishing the character of the organisms discussed and an attempt was made to restore the elements of the organic and inorganic environment.

One important result of the attempt to prepare a concrete illustration of these principles was the development of the conception that the similarity of organisms, or the homotaxial equivalency, may be determined by the environmental conditions independent of time equivalence, and that a propagation of environmental conditions, practically unchanged, across a considerable geographical area may carry with it a nearly identical fauna or flora, even though these conditions may, without break, successively transgress two or more distinct intervals of geologic time as determined by diastrophic criteria. This has been illustrated by an occurrence in the late Paleozoic, described in publication No. 283 of the Carnegie Institution.

It is obvious that work of this character can only be carried forward to the best results by the cooperation of a group of men, specialists in different fields, who will attack a definite problem from its various angles and by compilation and analysis of their results eliminate erroneous assumptions and results and produce positive results by a correlation of all the parts. Such a plan has been proposed to the Carnegie Institution in the suggestion for a department of palæogeography, and an effort is being made at present to solve certain elements of the problem by the committee upon sedimentation.

Under the grant it was proposed to carry out the studies in North America and then extend them to other regions of the world. The portion dealing with North America has been completed and published and a large amount of information has been accumulated concerning the late Palæozoic in other regions. The disturbed conditions caused by the Great War prevented contemplated visits to these other regions and the funds of the grant have been extended over a longer period than was contemplated originally and have been applied to researches in North America that were suggested in the course of the work.

One of the most interesting questions which has arisen is the apparently sudden extinction of the peculiar Permo-carboniferous vertebrate fauna of North America and the equally abrupt appearance of the late Triassic vertebrate life, in beds which are apparently continuous in deposition but barren of all traces of vertebrate life in the interval between the deposition of the remains of the two faunæ. In only one or two localities can a separation be made between the terrestrial deposits of the two periods by diastrophic criteria. Work was diverted to a search for a continuation of the Permo-carboniferous fauna in North America, as it continues in Europe and South

Africa, or an explanation of the lack of life, or the lack of preservation of remains, in the interval represented by the barren beds. These questions have not as yet been answered, but the search in the Triassic beds of Texas resulted in the discovery of some deposits of remains of stegocephalians and reptiles that are entirely new to science and distinct from the life of the same period in Europe. The study and description of these forms have resulted in publication of a preliminary description of the new suborder Desmatosuchia, the description of a cast of the brain-cavity of *Desmatosuchus*, and the description of a new species of *Ceratodus*, *C. dorotheæ*, the first reported occurrence of this genus in the Triassic of North America. Under preparation and in process of description are, first, a very perfect and undistorted skull of a new genus of stereospondylus stegocephalian, unique in the preservation of all the characters, which will be called *Buettneria perfecta;* second, a skull of a new genus of phytosaur of small size, retaining many primitive characters; third, a skull of a large phytosaur of a new species; fourth, a large number of isolated portions of the skeleton and armor of phytosaurs, teeth of undescribed fish, and coprolites. An expedition to the Triassic beds of Texas in the summer of 1921 resulted in the collection of more material, notably a very perfect skull of a large phytosaur, portions of the skeleton of a small dinosaur, and many other specimens of reptiles and stegocephalians. These specimens are now being studied for publication.

The completed results of this study will be submitted to the Carnegie Institution for publication as a contribution to knowledge of the fauna of the upper Triassic of North America; the results of the work in the Triassic of Texas have been so important that it will be continued for the present. It is intended that with the return of more settled conditions the original course of the work as defined under the grant will be resumed.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia. *Report on work done on the Pleistocene epoch and its vertebrate fossils.* (For previous reports see Year Books Nos. 11–19.)

At the time of making his last report the writer had been engaged in a study of the Pleistocene of Washington and Oregon and its vertebrate fossils. One of the very interesting formations of these two States is that named by Dr. J. Harlen Bretz the Satsop. This, so far as is now known, extends along the Columbia River from its mouth to the great lava plains east of the Cascade Range. To the same formation Bretz refers various deposits found along the coast of Washington and Oregon; also the deposit occupying the Williamette and Cowlitz valleys. Where the Columbia cuts through the Cascades the Satsop stands as high as 3,700 feet above sea-level, and it must have been laid down before, or about the time, the Cascade

Range began to lift its head. It is important to know the age of this deposit. If it is Pleistocene, as Bretz and Williams are disposed to regard it, the Cascades are geologically young. Fossil vertebrates in the deposits in the Cascades appear to be rare. Dr. Bretz has sent the writer a photograph of a tooth found in the Satsop of Gilliam County, Oregon, which appears to belong to the common mastodon of the Pleistocene. From ash beds near The Dalles, which seem to belong to the Satsop, Dr. Ira A. Williams has sent a tooth which the writer identifies as that of *Elephas primigenius*. These proboscidians appear to fix the beds in the Pleistocene. In case the deposits of the Willamette Valley are synchronous with the Satsop, the latter certainly belongs to the Pleistocene; for in that valley have been found elephants, mastodons, and two or three species of horses, among which is *Equus laurentius*, a not uncommon species in the Aftonian of the lower Missouri Valley. The fossils so found appear to indicate the first interglacial as the age of the Satsop. They do not, however, preclude the reference of the formation to the first glacial stage; and there are some reasons for connecting these deposits with those of the Idaho formation. In his report for 1920 (Year Book No. 19, p. 403) the writer by error referred this supposed oldest Pleistocene to the first interglacial instead of the first glacial.

The strip of country lying between the Front Range in Colorado and the Plains, only a few miles wide, has furnished an interesting series of vertebrates, all of which appear to belong to the early Pleistocene, probably the Aftonian. Horses and camels and *Elephas imperator* have been found at several places along this strip, especially in the so-called loess at Denver (Hay, Proc. U. S. Nat. Mus., vol. 32, pp. 599–603).

New Mexico furnishes few Pleistocene vertebrate fossils, but the geology is interesting and the fossils, which include horses and camels, are (at least mostly) those of the early Pleistocene. Near Zuni, McKinley County, a musk-ox, *Gidleya zuniensis*, has been found associated with a camel, thus carrying the musk-ox group back to the early Pleistocene.

In the paper just quoted (pp. 617–638) the writer has described a collection of mammals made at Anita, Arizona, about 40 miles north of Williams, on the railroad going to the Grand Canyon. About 15 species are described. Among the species found are two of horses (*Equus*), two of camels (*Procamelus*), and a large carnivore believed to be a hyena. These species are regarded as belonging to the first glacial stage of the Pleistocene, the Nebraskan.

Merriam, John C., and associates. *Continuation of Palæontological Researches.*

The purpose of this work has been to continue a group of investigations developed under the direction of J. C. Merriam in the course of the past twenty-five years. The specific aims of the researches relate to a study of the extinct vertebrate faunas of the Pacific Coast and Great Basin provinces of North America and to problems concerning history of life, evolution, geological sequence, and geographical history with which these researches are intimately connected.

As the idea of historical succession is basic to the investigations comprised in this study, it has been necessary to construct the outlines of geological history for the series of formations in which the vertebrate faunas have been secured. A large part of the area in which the studies are carried on is geologically almost an unknown land, and many of the regions in which palæontological collections have been made are those in which the geology is least satisfactorily understood.

In addition to a general geological study of the region in which the vertebrate faunas are obtained, it is necessary to know something of the conditions under which the deposits containing the faunas were formed. Such studies furnish information concerning the environment in which the life of past periods developed.

Continuation of the investigations under way has made necessary the close cooperation of a small group of persons whose interests touch specifically upon the geological and geographical succession, the history of climates, the history of the plant and animal life in general, and a special study of vertebrate groups available. Although many persons have been connected with work upon the problems concerned in past years, a cooperative arrangement has been in use involving especially, in addition to the researches of Mr. Merriam, the work of the following persons: Chester Stock, of the University of California, who has specialized upon the extinct mammalian faunas of the Pacific Coast and Great Basin province of North America; Ralph W. Chaney, of the University of Iowa, who has entered upon a fundamental study of the history of floras of the Pacific Coast region; John P. Buwalda, of the University of California, concerned especially with historical succession involved in the geology and geography of the region; and Remington Kellogg, of the Bureau of Biological Survey, United States Department of Agriculture, who has taken up anew a study of the evolution of marine mammals begun by him while in residence at the University of California. Fortunately, it has been possible to continue cooperation with all of the persons mentioned, and the advantages of such mutual support have been very large.

In conducting the researches during the past year we have been fortunate in having the active cooperation of the University of California, the Museum of History, Science and Art of Los Angeles, and the U. S. National Museum, together with the aid of many other agencies contributing to success of the work.

The University of California has graciously made available such quarters as are needed for use in work upon the collections of the Museum of Palæontology, and every needed assistance has been given by the University and by the staffs of several departments.

The Museum of History, Science and Art of Los Angeles has been most courteous in the offer of its splendid collections from the asphalt pits of Rancho La Brea. The Museum has not only furnished material but has cooperated through the use of its staff in every possible way to advance study of the collections to a point at which publication of the results may be possible.

The U. S. National Museum has offered quarters for work and has given every possible facility for the study of materials contributing in any way to an understanding of the problems involved.

The active operations in research have been based in a large measure upon collections assembled during the past twenty-five years and upon which the regular course of study was interrupted during the period of the Great War. Furtherance of the investigations under way has also required field work which has been carried on in the following regions: (1) asphalt pits of Rancho La Brea, California; (2) newly discovered Pleistocene asphalt deposits in the southwestern part of the Great Valley of California; (3) late Tertiary mammal-bearing deposits near Alturas, northeastern California; (4) many localities in marine Tertiary formations of the Coast Range region of California; (5) over a wide range of localities at which formations are found containing fossil plants in a region extending from Rancho La Brea in southern California, through northern California, western Oregon, and especially in the John Day region of eastern Oregon and the Snake River region of Idaho.

The field work at Rancho La Brea has involved only minor studies connected with the construction of a monograph covering description of the mode of occurrence of the remarkable deposit of mammal and bird remains found in the ancient asphalt beds at this locality. The first careful study of the fossil plants of Rancho La Brea was undertaken during the past year by Mr. Chaney, with the idea of securing as full information as possible regarding the flora of this region.

The investigations in the asphalt beds near McKittrick, on the southwestern side of the Great Valley of California, have included excavation work on a series of deposits containing a mammalian fauna from the Pleistocene or the period immediately preceding the present. These deposits have been known for many years and have furnished small quantities of bones from time to time. Not until recently has the deposit shown promise of furnishing large collections. The field work this year has brought forth abundant material with preservation not unlike that of the beds at Rancho La Brea, and representing a fauna similar to that of Rancho La Brea in many respects, but evidently either from a different environment or from a slightly different time-stage.

The work at Alturas, California, was conducted by Dr. Stock, associated with E. L. Furlong, of the University of California. The field studies this year were in continuation of work begun by a palæontological expedition from the University of California in 1920. Much interesting material was obtained. These collections, with those of the previous year, have made possible an age determination and a study of the relationships of this most interesting and heretofore unknown fauna.

The field work in marine formations was conducted by Remington Kellogg in association with Mr. Furlong. To assist in the monographic work in preparation by Mr. Kellogg, a number of excursions were made through the kindness of Mr. Furlong. These expeditions secured much material of interest, and the collections, added to those made by the University of California in the course of the past twenty years, open the way for a very important contribution on the evolution of the seal and whale groups.

The field work on fossil plants has been conducted by Ralph W. Chaney, who has been assisted in the field by Mr. Russell, of the University of California. Dr. Chaney's work was in continuation of studies begun by him in association with the University of California in 1920. Several typical localities in the Great Plains and Rocky Mountain region were examined for comparative purposes. The original localities at Rancho La Brea were visited and many minor stations in central and southern California were examined. The principal work relates itself to comparative studies of the numerous fossil floras of late geological stages known as the Tertiary. It extended through the marine formations of western Oregon, but concerned mainly the splendid floras in the Tertiary of the John Day region of eastern Oregon and in the Tertiary formations of southwestern Idaho, which are as yet imperfectly known. Very extensive collections of fossil plants have been secured and study of this material will furnish a large and important contribution to our knowledge of the history of plants in the Pacific coast and Great Basin regions.

The laboratory work conducted in connection with the studies under way has involved, first, the preparation of extensive collections for careful examination preliminary to description and interpretation. Much of the Rancho La Brea collection at the University of California still required freeing from the asphalt, and some of the most important of the marine mammal collections were inclosed in a rock matrix. Under the direction of Mr. Furlong, a large quantity of material was prepared for study, and through the cooperation of the U. S. National Museum other collections have been made ready for the researches of Mr. Kellogg.

Further important laboratory work has involved very extensive selection, assembling, and measurement of the great collections of Rancho La Brea material at the Museum of History, Science and Art of Los Angeles and at the University of California. This work has been done under the direction of Dr. Stock. It has involved a long-continued and painstaking review of the collections and has resulted in the securing of extraordinarily fine specimens for study. There has also been prepared, for final comparative work, the most extensive system of measurements ever based upon a collection of fossil mammals, so far as the writer is aware.

Special difficulties in the way of assembling the Rancho La Brea collections are found in the fact that the individual bones of many skeletons have been interwoven in an almost inextricable tangle, so that the parts of a single skeleton are often found scattered over the whole length, breadth, and depth of a given asphalt pit. In the present case, involving the study of hundreds of thousands of bones, the difficulty of adequate assembling has been enormously increased.

The laboratory studies have involved further the preparation of large series of illustrations comprising several thousand drawings and many hundreds of photographic plates, which must accompany the monographic studies. The necessity for such illustration lies in the fact that much of the material available is not accessible for other students, and it is therefore incumbent upon the authors interpreting this fauna so to illustrate the work as to convey the clearest meaning concerning the materials described. For a number of the papers illustrations are also planned which will represent as accurately as possible the approximate outlines of the living creatures whose skeletons are under examination. It is not intended that these outlines shall convey more than the sketch form, such as is indicated by the character of the bones and the evidence of muscular attachment. This series of studies has been carried forward in most satisfactorily by Mr. Charles R. Knight.

The results of work completed within the past year are embodied in seventeen papers prepared by members of the small group cooperating in the conduct of investigations described above. Of these contributions, eight are already in press and three or four will have been issued before this report is printed. Inasmuch as the list of titles covering publication does not fall within the period fixed for the date of the annual report, the titles are held for inclusion in the annual report of 1922.

As a summary of conclusions covering work of the year it may be stated that the investigations have contributed specifically to the advancement of research in the following directions:

1. Completion of two monographs on the remarkable Pleistocene fauna discovered at Rancho La Brea.

2. Completion of the first large paper on correlation of the formations and their contained faunas in the Great Basin province of western North America.

3. Completion of several papers covering description and relationships of faunas from Tertiary localities ranging from the San Francisco Bay region of California through Nevada, Oregon, and Idaho.

4. Carrying forward of the most extensive series of studies ever made in any one year on the problem of history and evolution of the whale and seal groups from regions bordering the Pacific Ocean.

5. Conducting the most productive series of comparative studies on the history and evolution of plants that has been made in any one year in the Pacific Coast region of North America.

There is ground for belief that the results of this work will contribute much toward an understanding of the specific problems of geology, biology, and history discussed. There is also reason to expect that the joint efforts of the several investigators engaged in these studies will help materially in our interpretation of the larger problem of interrelation between critical questions of geological history and those concerning biological evolution.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in Palæontology.* (For previous reports see Year Books Nos. 2–4, 6–9, 11–19.)

The reports in Year Books 18 and 19, taken consecutively, outline the course of cycadophyte investigation, with study of allied problems, virtually as pursued during the past year. No field work has been done, but considerable progress has been made in the elaboration of material, both of the petrified cycads and associated and other Mesozoic gymnosperms. Among various cycadeoids closely studied is the type in the State University of Iowa, *Cycadeoidea dacotensis.* The handsome and complete series of sections is of initial interest and unrivaled in studies of ancient plants. A new body of fossil gymnosperm material, with as broad a scope of interest as that on which either of the volumes I and II of the American Fossil Cycads is based, comes into view. It is not, however, to be inferred that elaboration is complete, while more exact illustration is one of the larger tasks ahead.

In adequate study of cycadeoid wood structure the range of Mesozoic coniferous wood characters must be brought into fuller view, and this can now be done more effectively than hitherto. We now have at hand a much increased section series of woods from the cycad horizons of our Northwest and also the excellent material for comparative study from South America mentioned in an earlier report.

It is intended to extend the section series and illustrate this material in somewhat better form for the botanical reader than photomicrographs alone would permit. These fossil woods are highly variable in conservation, and considerably more attention than is ordinarily possible in the isolated descriptions of species must be given to bring out real structure, unobscured by peculiarities of preservation.

There are exceptionally conserved conifer stems, but the great majority of the stems are disappointing when first seen under the microscope. Contrary to any first impression, the sections should always be extremely well made. The study of the features of conservation in a variety of specimens under the binocular shows why the greatest attention should be given in bringing both surfaces of a thin section down to the clearest possible polish. This being done, it is best to cover the duplicates alone with thin, close covers, in order that all structures may be examined under oil immersion and then drawn. We can not make headway in the study of the conifer woods in any other way. The photographs (enlarged 50) help for the general features, but do not afford the body of critical detail needed to reach final comparisons or to place relationships. Much less do photographs of greater enlargement make clear enough all the salient features.

In addition to the thin sections, the largest available well-polished transverse surface section should be had. It is the belief that any studies of growth-ring features, and larger climatic data of ancient forests not based on both the polished transverse trunk and thin sections, can not rise much above uncertainty. Growth-rings or rather growth-ring-like appearances are nearly omnipresent in petrified woods all the way back to the Carboniferous; but such often present great variations and peculiarities; they may appear to the eye as characteristic as in a northern oak, and then on examination, under even low powers, the rings may fade away as a mere result of crushing in the opaloid state, or even prove to be more or less discontinuous.

Many colloidal effects with inequal iron staining and carbon banding must arise during the course of petrification; and just as there is a nodular tendency in rocks to develop spheroidal banding, so in a petrified stem concentric cylindrical features often appear which are secondary to the wood structure, or which highly exaggerate (to the unaided eye) the more recondite stem structures and constitution. Thus there is an important banding effect in many stems due to what may be called shadow growth-rings, or "chemical growth-rings" as determined in present-day woods by Brown, while in other instances there are discontinuous zones of wood parenchyma.

The final value of the climatic indices afforded by the Mesozoic conifer forests like those of the Como, the Lakota, and the much earlier Shinarump of Arizona must remain indeterminate for a time longer, although it is probable that the ancient evergreen stands again and again stretched into climates as cool and changeable as southern Alaska. In both the Como and Lakota stems there are sharply outlined rings. For instance, in the Lakotan pityoxylons there is a long growth of open wood, followed by a discontinuous zone of parenchyma-surrounded resin canals. Dry-season wood is of slow, long growth, and sometimes an even growth of wood and quite confluent rings of several years indicate more evenly favorable seasons.

In several shorter notes in "Science," taken in conjunction with discussions of the Mesozoic cycadeoids, a theory of Mesozoic stem evolution is in reality brought out. It is believed that a basal scalariform type is seen in *Cycadeoidea* and that other old types were more araucaroid, that tracheids could by *relative* increase in size give rise to vessels and also decrease to the condition of fiber tracheids as especially held by Bailey, and that ray complication with development of storage tissue came rather late. It is not believed that the scalariform woods are less primitive than pitted woods. But it is clearer that, throughout the Triassic and down into the Cretaceous, the widespread to dominant conifers were of generalized structure. The wood is pine to araucaria-like, and the rays often quite simple. A large part of the ancestry of the recent types is doubtless within view.

One larger result of these studies is emphasized here. Recent anatomically based speculations of botanists, to the effect that herbaceous dicotyledonous stems are derivatives of woody types of mid to later Mesozoic time, find no support or comfort from either the positive or the negative side of the fossil-plant record. On the contrary, the most generalized of all Mesozoic fossil gymnosperm stems are indisputably the cycadeoids, and these, while including heavier wood types, easily find development far back as highly parenchymatous forms. Moreover, the conifer series from which systematists were but a short time since satisfied to derive the dicotyls are all through the Triassic and down into the Cretaceous characteristically conifers, and as such they change. Undoubtedly some forms closer to *Trochodendron* and *Drimys* than any yet found must occur, but the point is that the stem record is always a record of extreme parallelism, and so far the herbaceous dicotyl ancestry merely lacks detection. That it was little given to conservation was long since apparent, and the contention may be dismissed that absence from the Jurasso-Cretaceous rocks so far studied is significant. Direction of early dicotyl change, whether from or toward woody types, should eventually be detected from the study of fossils—especially so because of the wide prevalence of types from period to period, even extending to so peculiar an association as that of the curious fern *Tempskya* and the cycads.[1]

TEMPSKYA.

That twenty years of search in the Como and Lakota yielded no petrifactions other than cycads and conifers was a great surprise, even a cause of wonder. It seemed that of all the plants which flourished with the cycads, not a fruit or a stem aside from the abundant coniferous logs could be found. Had not hundreds of miles of outcrop been gone over repeatedly this might have been attributed to mere lack of observation, while objects so conspicuous as the cycads can not long escape notice. Yet, slowly, a sort of mental picture of the ancient conditions and reasons for this sparsity was formed from sights in the great pure-stand cactus forests of southern Mexico. It was there noted in the dry uplands how, in the short rainy season, muddy torrents form in a few minutes in the dry gullies of the cactus country and sweep all surface débris toward the lower lands. Even at night, as lit by incessant flashes of lightning, the old cactus stems could be seen rushing towards the lower lands, where many might be more or less silted in. And this suggests a parallel to the conditions in the Lower Cretaceous desert habitat of the cycads, with its odd and peculiar vegetation. In some such manner the large, compact types, together with the trunks of the fringing forests, were brought into the positions where silting went on, just as one may now see the log rafts forming at the head of Lake Chelan as brought down by the Stehekin River.

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[1] The distribution of an average type like the *Cupressinoxylon* from Europe to the Rhætic (?) of Argentina is, however, no less striking.

But an additional petrified type has at last been found in the cycad horizon. Last year Professor Knight, of Laramie, secured from the Lower Lakota of northwestern Wyoming the silicified stems of the strange pseudo-tree-fern *Tempskya*. This is the second occurrence for North America, much less well silicified forms having been described from the Potomac of Maryland several years since by Berry. Though thus far so rare for North America, *Tempskya* is of wide and long-known distribution in the European Lower Cretaceous. Briefly, this fossil fern, of structure little more complex than a bracken, branched repeatedly, to end in a crown-like summit, while innumerable aerial rootlets interlaced to form the quite compact pseudo stems, which may reach a foot in diameter and 10 feet or more in height. An exact parallel is afforded by an isolated Javanese species of *Hemitelia*, illustrated in the Buitenzorg Annals; while other species of the genus, more like other tree-ferns, reach south latitude 30° in the Natal *veldt* country, the general habitat of the cycad *Stangeria*.

The general inferences as to the climate of the Northwestern cycadeoid belt are thus slightly broadened by unexpected comparison with the South African cycad realm. But while from its Javanese occurrence, *Hemitelia* runs more toward the tropics, the heavy-stemmed Cretaceous cycadeoids have the appearance of plants able to withstand alike drought and snowfalls—probably more marked than those rarely reported from the limit of cycad occurrence in South Africa at south latitude 32° to 33°.

From the representative material of the Lakotan *Tempskya* trunks, kindly sent by Professor Knight, thin sections have been cut showing remarkably clear preservation. The stems at least 15 centimeters in diameter bore close-set foliage and have the same thick-set mat of pendent rootlets as the English and other European species, from which there is only specific separation.

SEVERAL PHENOMENA OF SILICIFICATION.

A recondite feature of the cell-walls observed only once in the foregoing *Tempskya* may have a bearing on the process of silicification. There are apparently present minute asymmetric rods with a clouded or little-defined enveloping zone, analogous to the siliceous rods isolated from cell-walls of living plants by Brown. And such rods, as suggested by Professor Charles S. Hastings in confirming their siliceous nature, might afford initial nodes of silicification. If so, plants with a larger silica content must tend to be the more susceptible to silicification.

But whether this view is correct or not, in the Como, silicification of the cycadeoids and conifers closely associated with the dinosaurs was a direct process. At the "Cycadella" locality in the Freeze-Out Hills, the large conifer stems may be soft and carbonaceous at one end and solidly silicified, or with only minute residual carbon, at the other, while trunks from deep shafts just over the coal at Aladdin, Wyoming, show roughly cylindrical, partly carbonaceous zones with more complete silicification, both interiorly and exteriorly. Undoubtedly such features deserve the attention of chemists and petrographers.

Petrifaction as seen in the great sauropod skeletons also presents features of sharp interest where the bones are partly to wholly silicified, the condition found at the old dinosaur quarries to the east of the Freeze-Outs, and 12 miles north of Medicine Bow. Examination of the polished surfaces, which are of great beauty of pattern, and of the histologically clear sections, shows the bones to be in some instances solidly silicified throughout. But there is certainly in places some remaining calcium. The lamellar net is quite black, as if retaining carbon, and uniformly surrounded by a brownish outer layer. The cancelli are filled with milky to bluish translucent quartz containing many inclusions. Just outside the bounding brown band is a less-defined zone of globules with the appearance of ordinary hyaline quartz, but without the nucleation of the spherules so characteristic of hyalite. The interspaces are often filled by amorphous quartz, but banded chalcedony is a frequent feature. In or about the hyaline zone are many small pyrite-crystal inclusions; those of largest size are isolated 0.1 mm. pyrite cubes of full luster. Pyritohedrons may be present and hexagonal tabulate forms may be iron carbonate (?). There are also flocks of minute doubly terminated quartz-crystal inclusions, all oriented in the same direction over considerable areas. It is easy to view this silicification as secondary, but the replacement of the calcium phosphates likely occurred at the time the carbon of the cycads and conifer logs was displaced by silica.

EVIDENCE OF ARIDITY IN THE LAKOTA.

Where the Lakota (=Cloverly) outcrops as the easterly extension of the Como Bluff about 16 miles easterly from Medicine Bow there occurs a remarkable series of tufas, often taking a globular form several feet in diameter. These are accompanied by quartz pebbles often smoothed to polished, and by very limy sands. And, as elsewhere noted, remarkable testimony as to the course of events during tufa accretion is afforded by the fact that the polished pebbles may be cleanly embedded far within the subradiate structure of the globular tufas. Evidently the pebbles like the well-known "dreikanter" type, belong to desert surroundings, just as the tufas are best explained as depositions along the shores of salines or recedent lakes. Just where precisely similar conditions may be found to-day is not yet determined, although a very near approach is seen in the tufas of the Lake Lahontan shore-lines. But some variation in the character of tufas so far separated in time is to be expected, since (at least theoretically) temperature, salinity, and the character of the conditioning algal life must be the slightly changing factors of deposition. Extension of this trend or shore-line is indicated by tufas like those of the Como Bluff region, also said to occur about 5 to 13 miles further east (in the southwestern part of township 25). The forms are darker, rather smaller, harder, and more siliceous. The polished pebbles, often of 5 or 6 pounds in weight, have been seen in the Lakota in great numbers, and the data of these occurrences should be carefully assembled. Such pebbles could and must often have been swallowed by larger reptiles, but in view of widespread occurrence and varying character the so-called "gastroliths" must be limited to the isolated polished-pebble groups actually noted in rib or thoracic association, instances of which are of more or less authentic record. The polished shore-line pebbles are, then, most widely distributed in the Lakota, although first reported from a sauropod association in the Como. In the latter formation they may also prove abundant, as it is stated (by Knowlton) that in the Big Horn Basin, 5 miles west by north of Ten Sleep, the varicolored beds (Como) are in many places characterized by the gastroliths. Two cycadeoids, *Zamites arcticus* Heer and *Nilssonia nigricollensis* Wieland, occur in this locality. They also may accord with a very dry climate.

Altogether, the remarkably curious evidence bearing on the climate of the northwestern Lower Cretaceous seems to have long escaped notice. Moreover, the assemblage of data becomes far more important than can any attempt to reach at once a fixed or set view. There is the promise that much more can yet be learned of the climatic environments indicated by the Como and Lakota plants, even though the number of recovered leaf-imprint species should remain small.

During the present year the private laboratory unit at "Anawan" (near the Oyster River, Connecticut), mentioned in Year Book No. 13, has been further equipped and much used. The only outside cooperation to record is that generously given by the Harvey & Lewis Co., opticians of New Haven. Their men, skilled in the art of accurate lens-grinding, have taken interest in the art of thin-section cutting and have helped materially in the preparation of sections fulfilling the fine requirements set forth above.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–19.)

Dr. Barus has presented to the Carnegie Institution a report embodying applications of displacement interferometry, together with the correlative work which has grown out of such applications.

In the introductory paper the open mercury manometer is made directly available for pressure measurement. The sensitiveness per fringe displacement being easily a few hundred thousandths of a centimeter of mercury, applications to air thermometry on a micronometric scale and an attempt to revive the old absolute electrometer are made incidentally.

A more suitable field for testing the immediate capabilities of the interferometer U-tube is detailed in the following chapters, which exhibit the pressure and dilation observable in a region vibrating acoustically. If this is quite closed, or quite open to the atmosphere, the record of the U-tube within is of little interest; but if the region is all but closed—open, for instance, through a pin-hole less than 0.5 mm. in diameter—the gage shows pronounced fringe displacements, as a rule, and particularly at the frequency of the harmonics. If the sound generator is a telephone, the displacements are proportional to the effective currents actuating it, and at the harmonics much more than 10,000 ohms may be put in circuit before the fringes cease to move appreciably. Similarly, under low resistance, very small fractions of a semitone are registered and the ear becomes a poor apparatus for discrimination. The investigations are made along two lines, in the first of which the sound generator and the U-tube lie within the boundary carrying the pin-hole; in the second the sound generator lies without and is independent, so that the pin-hole valve carried on a long tube becomes an appropriate probe, or sonde, for the pressures within sounding-pipes. As all the harmonics are thus saliently registered, there should be no serious difficulty in exploring the acoustics of the mouth-cavity uttering word sounds, for instance. A curious result of the survey of the distribution of pressure increments in relation to pitch is the replacement of pressures by dilations in different orders of frequency.

Developments of the direct interferometry of the compression of a sound-wave follow; but only as much is given as is necessary for the coordination of the other chapters. The method used is superior to the earlier solutions of the problem, in its greater flexibility and the ease with which fringes in any orientation may be produced and shortened to a string of silvery beads. The simple organ-pipe blower, or adjustible embouchure described, will be found serviceable for many other purposes, both of research and instruction.

As the telephone is an indispensable convenience throughout these papers, an interferometer investigation on the vibrations of the plate of that remarkable instrument is inserted. What comes out definitely in the research is the readiness of the plate to quiver in overtones, after each electromagnetic shock. A small mirror at the center is not therefore displaced (as a rule) translationally, but rather rotationally, giving rise to very complicated wave-forms, difficult to analyze. In corroboration of this, it was found later that a telephone current may often be commutated.

The endeavor to place the Foucault mirror on the interferometer has, for incidental reasons, thus far failed of achievement; but as a variety of apparatus useful in experiments of the present kind were tried out in the course of the work, a brief account of it is given.

In deference to the wishes of Dr. R. S. Woodward, the author has begun a search for methods of measuring the acceleration of gravity other than those classically in use. Such an inquiry necessarily consists in referring gravitational pull to forces generated in other mechanisms. An interferometer torsion balance is first tested; but the results are found to encounter relatively large and uncontrollable temperature coefficients, both of rigidity and viscosity, even if the ordinary effects of viscosity can be allowed for. The other (pneumatic) method for g, in which gravitational force is referred to the pressure of a gas, has at the outset much to recommend it; for it admits of rough treatment, in spite of the otherwise surprising precision of results. The two errors which offer a serious menace to the accurate hydraulic weighing of the cartesian diver, viz, the diffusion and solution discrepancies, though at first approach apparently insuperable, may not remain so indefinitely. At least, in experiments on the diffusion and convection of gases in narrow tubes made in the lapse of years, coefficients of a negligibly small order of value were obtained. Though the work is very laborious, it seems worth while to carry it further.

The remainder of the volume is largely concerned with work bearing on the constant of gravitation. The object of these experiments was at the outset a mere endeavor to read the deflections of the gravitation needle by displacement interferometry. The plan succeeded at once, but on computing the Newtonian constant it came out actually several times too large. It was obvious that this could be explained only by the presence of relatively large radiant forces. In the course of the work, the latter, in some mysterious way, were almost always found to act in the same sense as gravitation. Hence the need of tracing the radiant forces to their source and, if possible, to learn to control them, became urgent. Much of the succeeding paper is given to work of this kind. Among other things, the attempt is made to refer the constant of gravitation to the viscosity of the medium in which the needle moves. The most curious results in relation to the radiant forces were obtained by submerging the whole of the gravitational apparatus in a capacious water-bath well stirred, so that the temperature varied but a few tenths of a degree per day. Notwithstanding these apparently ideal conditions, the needle simply drifted and showed no response to gravitation whatever. The best method of reducing the radiation discrepancy, thus far found, is an exhaustion of the case containing the needle. Results so found came within 1 per cent of the normal value, but were still in excess. No doubt this is far from precision; but it is a great advance from the original error of several hundred per cent of excess.

In concluding papers the author has put together a number of incidental results, bearing on the breakdown of molecular instabilities as evidenced by the peculiar phenomena of residual viscosity. In a similar experiment, showing the magnetic set in iron produced by an electrical current passing through it, there occurs, as it were, an element of hysteresis. A useful method for the production of two groups of independent fringes, present in the same field, is finally given.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream-flow.* (For previous reports see Year Books Nos. 12–16, 19.)

One year ago the investigation had reached the stage in which it was clear that the next step must be to complete the evaluation of fluctuations in elevation of the water-surface at each recording-gage, from day to day, due to the variations in direction and in velocity of the winds blowing over the surface of each lake and the variations in the barometric gradients over that lake. The ultimate object of this investigation is to obtain a much better formulation than the engineering profession now has of the laws governing the amount of stream-flow. The immediate object of the investigation is to determine the laws of evaporation from a large water-surface with much greater accuracy than they are now known. For this purpose it is proposed to consider each of the Great Lakes in turn as an evaporation pan and to evaluate change of content, income, and outgo, including evaporation.

One year ago the evaluation of wind effects had made much progress, but was far from complete. It is now complete.

During the year the evaluation of the barometric effects on Lakes Erie and Lake Michigan-Huron has been completed.

A publication setting forth fully the results of this part of the investigation is now ready for the printer under the title, "Effects of Winds and of Barometric Pressures upon the Great Lakes."

The effects on the elevation of water-surface of changes in the barometric gradient over each lake have been found to be larger than they have ordinarily been supposed to be. For example, the barometric gradients over Lake Michigan-Huron caused the water-surface at the Milwaukee gage to be above, or below, the mean elevation of the surface of the whole of Lake Michigan-Huron by 0.20 foot or more for a whole day on eight different occasions during the eight months of 1910 and 1911 which have been studied carefully. The extreme case occurred on July 25, 1911, when the disturbance of elevation, in the sense just defined, averaged for the day 0.30 foot, the water surface at Milwaukee being below the mean elevation of the whole lake surface.

The barometric effects have probably been mistakenly identified as wind effects in frequent cases in the past.

The constants of the formulæ for barometric effects must be derived separately for each gage station. The general method of determining the constants which has been developed is, however, applicable on any body of water in the world.

The formula for the wind effects, and also the constant in that formula as derived from the observations, are both of general application on any free water-surface, on any lake, on the open ocean, or on any gulf, bay, or river.

The maximum wind effect found at any of the five stations, Buffalo, Cleveland, Milwaukee, Harbor Beach, and Mackinaw, during the period covered by the investigation was 1.00 foot at Buffalo on October 27, 1910, for a single hour at 10 a. m., when the wind was 53 miles per hour from the southwest. The maximum wind effect found at Cleveland was 0.19 foot at 7 a. m. of that same day. The wind effects at the three gage stations mentioned on Lake Michigan-Huron were found to be very small—as a rule less than 0.01 foot. The maximum at these three stations within the limits of the investigation was 0.03 foot. It is clear that the wind effects are much greater than this in some of the shallow bays tributary to this lake. In general, wind effects in the main portions of Lake Michigan-Huron are very much smaller than on Lake Erie. The contrast arises from the fact, now well demonstrated, that the wind effects are inversely proportional to the cube of the depth of the water. The average depth of Lake Michigan-Huron is much greater than that of Lake Erie.

It is now clear, from the investigations, that the application of corrections for barometric effects and wind effects greatly increases the accuracy with which the elevation of the mean surface of a lake may be determined from the observations at a given gage. For example, the mean elevation of the whole surface of Lake Erie may now be determined as accurately from a single day of observation at Buffalo, corrected for barometric and wind effects, as it could formerly be determined from 16 days of uncorrected observations at that gage. Buffalo is a place of very large wind effects and moderately large barometric effects. Even at Milwaukee, where the wind effects are almost negligible, the increase in accuracy gained by correcting for barometric and wind effects is sufficient to insure that the mean elevation of the whole surface of Lake Michigan-Huron may be determined as accurately from 1 day of corrected observations as it could formerly be determined from 4 days of uncorrected observations.

It is important to determine the fluctuations in the elevation of the mean surface of each lake, because such fluctuations are the measure of the variations in the total water-content of the lake.

The application of the corrections for barometric effects and wind effects give a sound and accurate basis for the proposed investigation of evaporation.

Nichols, E. L., Cornell University, Ithaca, New York. *Report on studies in luminescence.* (For previous reports, see Year Books Nos. 4–19.)

On the subject of the excitation of fluorescence by the hydrogen flame, to which reference was made in the Year Book for 1920, four papers have been published, as follows:

Luminescence at high temperatures: E. L. Nichols and D. T. Wilber.
Flame excitation of luminescence: E. L. Nichols and D. T. Wilber.
The luminescence of certain oxides sublimed in the electric arc: E. L. Nichols and D. T. Wilber.
The spectral structure of the luminescence excited by the hydrogen flame: H. L. Howes.

Since the completion of these investigations our studies have been directed to another phenomenon, described as follows.

THE BLUE GLOW.

This is a luminescent effect which is superimposed upon the ordinary temperature radiation of certain oxides. In so far as this effect has been noticed hitherto, and it is too obvious to have escaped attention altogether, it has been designated as "selective radiation," and having been given a name it has been ignored. That the *blue glow* is a type of luminescence will appear clearly from the following characteristics already established in the course of the investigations now in progress by Professor Howes and the writer:

(1) It is characteristic of two groups of oxides: (*a*) of the oxides of calcium, magnesium, beryllium, zirconium, silicon, and aluminum; (*b*) in somewhat modified form, of such of the rare earths as have been tested, i. e., the oxides of samarium, gadolinium, præsodymium, neodymium, erbium, and cerium.

(2) In group (*a*) the radiation in question is chiefly that lying within a broad blue band in the spectrum.

(3) The effect is most strikingly obtained by heating the oxide directly in the oxy-hydrogen flame, but it occurs when other means of heating are used.

(4) There is a definite temperature range within which the blue glow begins, reaches its maximum, and disappears. This differs with the individual oxides, but in all cases thus far examined the limits are found between a dull red heat and 1200° C.

(5) *The effect accompanies and is probably intimately related to the transformation of these oxides from transparency to opacity and their change from dielectrics to conductors of electricity.*

(6) It is subject to fatigue.

(7) It is profoundly modified by previous heat-treatment of the oxide.

(8) It occurs in oxides which are non-luminescent under photo-excitation or the action of X-rays, but which are capable of kathodo excitation.

(9) Unlike kathodo-luminescence and photo-luminescence of the oxides, this type of luminescence does not appear to depend upon the admixture of an activating element. It is, however, sometimes profoundly modified by the presence of such admixtures.

(10) The effect is by no means confined to the blue, but may be observed in other parts of the spectrum. It yields intensities very many times greater than that of the black body for the same temperature and wave-length. The intrinsic brightness is thus vastly greater than that of any known luminescent surface at ordinary temperature.

Kathodo-Luminescence of the Oxides.

Another outcome of the discovery of the flame excitation of luminescence, announced last year, is the systematic investigation by Mr. D. T. Wilber and the writer of the kathodo-luminescence of the oxides, such as CaO, MgO, BeO, Al_2O_3, SiO_2, which had been found active in the hydrogen flame.

The behavior of these in the kathode tube, as was to be anticipated from the work of Crookes, Urbain, and others, is much more complicated than their flame luminescence. We find that the various minute admixtures of chromium, manganese, etc., which are incapable of detection by means other than that of the character of the luminescence spectrum, require different degrees of heat to render them active. Thus a sample of aluminum oxide may be made to fluoresce green, red, or blue, according to the precise temperature to which it is exposed.

Luminescence of Beryllium Oxide.

Beryllium oxide is a new member of this very interesting group, and its luminescent properties, which hitherto have not been investigated, are now being studied. We find this oxide to be unaffected by light or ultra-violet rays, almost completely inert under exposure to X-rays, finely fluorescent in the kathode tube, after heating, and highly responsive to excitation by the hydrogen flame.

Between 500° and 1200° C. it exhibits markedly the *blue glow*.

Luminescent Flames.

That the light from flames containing various salts is due to luminescence was suggested many years ago by E. Wiedemann, and experimental evidence in favor of this view was given by Ebert in 1891. Certain physical chemists, particularly Trautz and Bancroft and Weiser, in their papers on *flame reactions*, have taken a similar position.

We find by a study of the spectra of these flames abundant further confirmation of this theory. In every case examined the structure of the spectrum conforms to the general type of luminescence spectra, being made up of series of bands having a constant frequency interval.

Other Studies in Progress.

Mr. J. A. Becker is determining the temperature range through which substances excited to luminescence by X-rays are active and is comparing the spectra of bodies thus excited with the corresponding photo-luminescence.

Mr. H. N. Kahler is investigating the possible relations of photoelectricity to luminescence and is studying the possible changes of crystal form produced by the heat treatment of oxides necessary to bring out their luminescent properties.

Professor Frances G. Wick is making a spectrographic study of the kathodo-luminescence of the fluorites. This is to include the identification of the narrow bands, the origin of which has long been a matter of controversy, and the determination of the effect of heating upon the spectral structure.

Mr. L. J. Boardman is determining, by a photographic method, the specific activity of different wave-lengths of light in producing fluorescence.

Dr. J. O. Perrine has just completed a search for ultra-violet fluorescence in inorganic substances under the excitation by X-rays. The uranyl salts were found to be universally inactive beyond the range of the green-blue bands already known. Of 23 oxides examined, ZnO is the only one fluorescing in this region of the spectrum.

The following substances were found to exhibit fluorescence in the ultra violet: LiCl, NaCl, KCl, RbCl, CsCl, CdCl, HgCl, $KLiCl_2$, KBr, KI, CuI_2, CdI.

Willemite and calcium tungstate, in addition to their well-known brilliant fluorescence in the visible spectrum, were found to be active in the ultra-violet when subjected to X-rays.

Miss Ruth Yeaton, in a paper soon to be published in the Physical Review, describes an investigation of the effect of concentration of the electrolyte in the photo-active cell, Pt-Rhodamine-B-Pt, on the form of the current-time growth-curve and upon the sensitiveness of the cell. She also describes the effect of the age and the previous illumination of the electrolyte on the current characteristics.

Mr. Frederick May has investigated the effect of a difference in temperature of the two electrodes of the Pt-Rhodamine-B-Pt cell upon the value of the dark current described in the recent paper by C. C. Murdock.[1] His results are now being confirmed by another series of experiments.

Incidental to the main purpose of Professor Murdock's work referred to above, it was found necessary to measure the polarization capacity of the Pt-Rhodamine-B-Pt cell. This measurement is difficult because of the high resistance of the cell, which seriously interferes with the attainment of precision by any of the methods ordinarily used. This problem has been undertaken by M. W. Pierce, K. F. Sun, and I. Wolff. Mr. Wolff and Mr. Sun have each developed new methods of attacking the problem. The methods have been shown to be entirely satisfactory and experimental work with the cells is now under way.

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[1] C. C. Murdock: Physical Review (2), Vol. XVII, p. 627 (1921).

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